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The Quest for Stellar Parallax

By DORRIT HOFFLEIT

The history of the successful determination of the distances of the stars is scarcely more than a century old. In 1838 and 1839, within a few months of one another, Bessel, Henderson, and W. F. G. Struve independently achieved the first trustworthy results. After their pioneering successes, further progress was slow, but nevertheless steady. At the end of fifty years hardly fifty parallaxes had become known. The second half of the century that has elapsed since the time of Bessel has, on the other hand, showed remarkable advancement. Not only has the number of stars with well-determined trigonometric parallaxes increased to about four thousand, but other (indirect) methods have been discovered and perfected. Among these, the spectroscopic and dynamic methods and the application of the period-luminosity relation are especially important. As a consequence of improved technique in the older methods and the abundant utilization of newer methods—all of which owe their major successes to the rise of photography—we now know the parallaxes of over 10,000 individual stars.

Preceding an enumeration and description of the various methods available for the derivation of stellar distances, however, a brief résumé of investigations and reflections during what we may designate the "prehistoric period" of stellar parallaxes seems appropriate. For it is the philosophy, the ideals and ambitions, the less mature "clues," and in a large measure the very failures of our predecessors that have nourished the seeds of highest accomplishment in our own era.

The Pre-Parallax Era. In about 265 B.C. Aristarchus of Samos estimated from the angle between the sun and the moon at the times of exact quarter moon, that the sun must be twenty times the more distant. His estimate was off by a factor of about twenty. Yet it is historically important as being the first known attempt at a geometric determination of the distance of a celestial object. It was the first to indicate that the sun is far more distant than the moon and therefore much larger. Aristarchus went further. From the relative diameters of the moon and the earth's shadow during a lunar eclipse, he inferred that the sun is much larger than the earth; hence that the earth probably revolves around the sun. We might dwell long on Greek astronomy and its relation to the general parallax problem; but this is the significant starting point, beyond which little real progress was made for more than a millenium and a half. Aristarchus had shown that the motion of the earth should give the stars an apparent periodic

motion, the size of the parallactic ellipse depending on the distances of the stars. No parallactic motion was observed. He therefore concluded that the stars are extremely remote. On the other hand, Ptolemy, four centuries later, interpreted the negative parallax results as evidence for a fixed earth relative to the fixed stars. Much of Galileo's suffering in the seventeenth century must be attributed to the fact that the parallaxes of the stars (all well under one *second* of arc) were too small to be so much as suspected from the measurements with the most accurate instruments of the time,—instruments whose limiting precision did not permit the detection of displacements of one *minute* of arc. Not even in Halley's time were the instruments sufficiently precise for the measurements of relative displacements smaller than about 15″.

The handicap of inadequate measuring devices was not the only obstacle to the discovery of stellar parallaxes. When shifts in star positions were finally, laboriously but certainly, observed, numerous sources of apparent motion besides parallax were discovered,—motions either of the same order of magnitude as the expected parallaxes, or larger. Thus, efforts, apparently unavailing in their intended goal, actually opened up previously unsuspected fields for investigation (for example, Herschel's work on double stars). Meanwhile the lower limit for the distances of the stars was steadily increased from the 200 astronomical units estimated by the late Pythagoreans, to 4000 in Galileo's time; Newton estimated it to exceed 20,000 (*cf.*, "Cambridge Readings in the History of Science," p. 42, 1924); and finally the distance of the first star to reveal its parallax was found to be 700,000 astronomical units.

Proposal of Relative Parallax. It was Galileo, believing the "fixed stars" not to be actually fixed, who proposed ("Third Dialogue in the System of the World") that the positions of the brighter stars should be carefully watched relative to their faintest neighbors. For, on the assumption that all stars are intrinsically of comparable luminosity, the brighter stars are the nearer. The faint stars should therefore serve as a reference frame for measuring the parallaxes of the bright stars. The proposal of this method reappeared, independently, many times in parallax history. Huygens, for example, tried it unsuccessfully in about 1750. Sir William Herschel's monumental investigations and discovery of binary stars begun in 1782 (*Phil. Trans.*, **72**, 82, 1782) originated entirely in his hope of determining the relative parallax of two stars of a pair which he considered purely optical. For many years he adhered to his belief that close pairs were purely optical companions, even though Bradley had previously indicated the true binary character of at least one such pair (the Castor system, in which the position angle had changed by 30 degrees between 1718 and 1759) and despite Michell's argument in 1767 against the chance coincidence of as many optical companions as had already been observed.

Changes in Star Positions. Among the various sources besides parallax that may contribute to small changes in the position of a star, we

may mention precession, nutation, and aberration due to the earth's motion; refraction in the earth's atmosphere; proper motion and orbital motion of the star; and the solar motion. Many of these were discovered for the first time during the pursuit of parallaxes.

Precession. Precession, evidenced by the shift in the apparent positions of the stars due to the changing direction of the earth's axis, had already been discovered by Hipparchus, probably before 125 B.C. He found, for example, that his position for Spica preceded the autumnal equinox by only 6° whereas Timocharis and Aristyllus, 130 years previously, had noted a difference of 8°. This sort of change was corroborated by observations of other stars and he interpreted it as arising from a progressive motion of the vernal equinox amounting to about one degree in a hundred years (Wolff, *Geschichte u. Literatur d. Ast.*, **2**, 400, section 200, 1891). Newcomb's value is $50''.2564 + 0.000222$ $(t - 1900)$.

Proper Motion. While making a study of the precession of the equinoxes, Edmund Halley in 1718 compared star catalogues of his own time with those of Ptolemy and Hipparchus. He thereby discovered that four bright stars, Sirius, Aldebaran (called Palilicium), Arcturus, and Betelgeuse had changed their positions in a manner contrary to the effects of an assumed greater obliquity of the ecliptic: the first three stars he found 15′ to 30′ farther north than expected, while Betelgeuse was a whole degree farther south than in Ptolemy's time. Nor could these differences be ascribed to observational or transcriptional errors, since the observations of Ptolemy, Timocharis, and Hipparchus were in good agreement with one another. Halley therefore concluded that "these stars, being the most conspicuous in Heaven, are in all probability the nearest to the earth; and if they have any particular motion of their own, it is most likely to be perceived in them, which in so long a time as 1800 years may show itself by the alteration of their places, though it be utterly imperceptible in the space of a single century of years" (*Phil. Trans.*, **30**, 736, 1718). This is how the evidence for stellar proper motions was first announced.

Aberration. Nutation and aberration were both discovered by Bradley. When he and Molyneux in 1725 measured the positions of gamma Draconis for parallax, they were surprised to find that the positions did not vary at all in accordance with predicted parallax factors. At first Bradley supposed that nutation of the earth's axis might account for the apparent motion of the star. But upon examining measurements for a faint star at the same polar distance as gamma Draconis, but differing from it by twelve hours in right ascension, he found his hypothesis unsatisfactory. If nutation were to account for the observations, both stars should have experienced nearly the same displacements, whereas the faint star, eta Ursae Majoris, had appeared to move only half as much as the other. Bradley then studied many stars. Various hypotheses occurred to him, and at last he hit upon the correct

explanation, "that all the phaenomena hitherto mentioned, proceed from the progressive motion of light and the earth's annual motion in its orbit. For he perceived that, if light was propagated in time, the apparent place of a fixed object would not be the same when the eye is at rest, as when it is moving in any other direction, than that of the line passing through the eye and the object; and that, when the eye is moving in different directions, the apparent place of the object would be different" (Rev. James Bradley: "A new Apparent Motion discovered in the Fixed Stars; its Cause assigned; the Velocity and Equable Motion of Light deduced." *Phil. Trans.*, **35**, 637; Abridged, **7**, 313, 1728). We quote his further conclusions: "The hypothesis gives at least the true law of the variation of the declination in different stars, with respect to their different situations and aspects with the sun. And if this is the case, it must be granted, that the parallax of the fixed stars is much smaller than has hitherto been supposed by those, who have pretended to deduce it from their observations. Mr. B. . . . thinks that if it were 1″, he should have perceived it in the great number of observations he made, especially of γ Draconis; which agreeing with the hypothesis, without allowing anything for parallax, nearly as well when the sun was in conjunction with, as in opposition to, this star, it seems very probable that its parallax is not so great as one single second. . .

"There appearing therefore after all, no sensible parallax in the fixed stars, the anti-copernicans still have room on that account, to object against the motion of the earth." This cynical statement is, of course, refuted by the test of the very hypothesis he was forwarding: but for the motion of the earth, aberration of starlight could not have been observed.

Nutation. Twenty years later, in 1747, Bradley's first clues about nutation became verified. He wrote (*Phil. Trans.*, **45**, No. 485, p. 1, 1747/8), "The great exactness with which instruments are now constructed has enabled the astronomers of the present age to discover several changes in the positions of the heavenly bodies; which, by reason of their smallness, had escaped the notice of their predecessors." As soon as Bradley had settled the problem of aberration, his attention had been called to further unaccounted-for annual changes in the declinations of some stars. For twenty years he continued with his observations, confessing "When I shall mention the small quantity of the deviation which the stars are subject to, from the cause that I have been so long searching after, I am apprehensive that I may incur the censure of some persons"; but the thirst for truth prodded him on. His observations indicated that "some of the stars near the solstitial colure had changed their declination 9″ or 10″ less, than a precession of 50″ would have produced; and at the same time, that others near the equinoctical colure had altered theirs about the same quantity more." Considering these circumstances he suspected them of being due to the moon's action on the equatorial bulge of the earth: "The plane of the

moon's orbit being at one time, above 10° more inclined to the plane of the equator than at another; it was reasonable to conclude that the part of the whole annual precession, which arises from her action, would in different years be varied in its quantity; whereas the plane of the ecliptic, in which the sun appears, keeping always the same inclination to the equator; that part of the precession, which is owing to the sun's action, may be the same every year: and hence it would follow, that though the mean annual precession, proceeding from the joint actions of the sun and moon, were 50″; yet the apparent annual precession might sometimes exceed, and sometimes fall short of, that mean quantity, according to the various situations of the nodes of the moon's orbit."

On the star gamma Draconis, Bradley had made over 300 observations. When he had corrected all the positions for precession, aberration, and nutation not a single value was found that differed from the mean position by as much as 3″; and only eleven of the three hundred deviated as much as 2″. The magnitudes of the various corrections are well brought out in Table I, transcribed from Bradley's account (*Phil.*

TABLE I

BRADLEY'S ABSTRACT OF OBSERVATIONS OF γ DRACONIS

Date	South of 38° 25′	Precession	Aberration	Nutation	Mean Distance
1727 Sept. 3	70″.5	— 0″.4	+19″.2	—8″.9	80″.4
1728 Mar. 18	108.7	— 0.8	—19.0	—8.6	80.3
Sept. 6	70.2	— 1.2	+19.3	—8.1	80.2
1729 Mar. 6	108.3	— 1.6	—19.3	—7.4	80.0
Sept. 8	69.4	— 2.1	+19.3	—6.4	80.2
1730 Sept. 8	68.0	— 2.9	+19.3	—3.9	80.5
1731 Sept. 8	66.0	— 3.8	+19.3	—1.0	80.5
1732 Sept. 6	64.3	— 4.6	+19.3	+2.0	81.0
1733 Aug. 29	60.8	— 5.4	+19.0	+4.8	79.2
1734 Aug. 11	62.3	— 6.2	+16.9	+6.9	79.9
1735 Sept. 10	60.0	— 7.1	+19.3	+7.9	80.1
1736 Sept. 9	59.3	— 8.0	+19.3	+9.0	79.6
1737 Sept. 6	60.8	— 8.8	+19.3	+8.5	79.8
1738 Sept. 13	62.0	— 9.6	+19.3	+7.0	78.7
1739 Sept. 2	66.6	—10.5	+19.2	+4.7	80.0
1740 Sept. 5	70.8	—11.3	+19.3	+1.9	80.7
1741 Sept. 2	75.4	—12.1	+19.2	—1.1	81.4
1742 Sept. 5	76.7	—12.9	+19.3	—4.0	79.1
1743 Sept. 2	81.6	—13.7	+19.1	—6.4	80.6
1745 Sept. 3	86.3	—15.4	+19.2	—8.9	81.2
1746 Sept. 17	86.5	—16.2	+19.2	—8.7	80.8
1747 Sept. 2	86.1	—17.0	+19.2	—7.6	80.7

Trans., **45**, 1747/8; Abridged, **9**, 430). Similar results in confirmation of his theories of aberration and nutation he found in his observations of numerous other stars.

Solar Motion. In the same revealing paper (p. 437) Bradley already suggests secular parallaxes: "For if our own solar system be conceived to change its place, with respect to absolute space; this might, in process of time, occasion an apparent change in the angular distances of the fixed stars; and in such a case, the places of the nearest stars being

more affected, than of those that are very remote; their relative positions might seem to alter; though the stars themselves were really immovable. On the other hand, if our own system be at rest, and any of the stars really in motion, this might likewise vary their apparent positions; and the more so, the nearer they are to us, or the swifter their motions are, or the more proper the direction of the motion is, to be rendered perceptible by us. . ."

The effect of secular parallaxes or solar motion was more specifically stated by Tobias Mayer who, in 1756, compared it with "the separating in front and closing up behind of trees in a forest to the eye of an advancing spectator" (Agnes Clerke, "History of Astronomy During the Nineteenth Century," 4th Ed., p. 15, 1902). But in his examination of 57 stars with proper motions exceeding 10″, Mayer could find no observational evidence either for or against solar motion. It was not until 1783 that solar motion received definite observational support through Herschel's investigations. From the proper motions of the bright stars he found the apex to lie in Hercules or Lyra, or the antapex near Orion (*Phil. Trans.*, **73**, 247, 1873). In view of the scarcity of his material, his determination is remarkably close to the results from extensive modern data.

Refraction. In the course of his search for parallax, Bradley did not fail to comment on refraction, and to recommend (*Phil. Trans.*, **9**, 438, 1747/8) that observations be made near the zenith where refraction is small. The phenomenon of refraction was first recognized probably as early as the time of Ptolemy. (Atmospheric refraction is discussed in a treatise on optics which is sometimes attributed to Ptolemy. *Cf.*, Arthur Berry, "A Short History of Astronomy," p. 62, 1899.) Bernard Walter, a pupil of "Regiomontanus" in the fifteenth century is credited with the first successful attempts at allowing for refraction in his observations. Kepler improved the theory in a treatise on the application of optics to astronomy. But it was Willebrord Snell (1591-1626) who formulated the law of refraction. Somewhat later Cassini (1625-1712) calculated new refraction tables that were more accurate than Kepler's. Edmund Halley, however, in publishing tables determined by Newton, seems to have overlooked some of the earlier results when, in 1721, he wrote, "But as it is so little, that none but nice instruments can perceive its effects, it was not discovered to be any at all, till Bernard Walter's time, about the year 1500; nor brought to any sort of rule till Tycho Brahe; nor ascertained, till our worthy president (Newton) made the first accurate table of it" (*Phil. Trans.*, **31**, 169, 1721; Abridged, **6**, 517).

Instrumental Errors. Thus most of the factors that must be eliminated from the observations before it becomes possible to solve for the parallax of a star were adequately understood well before the beginning of the nineteenth century. The further improvements that were necessary were mainly instrumental: greater accuracy in the measure-

ments themselves was required. Indeed the errors of the instruments frequently contributed spurious parallaxes. Pond (*Phil. Trans.*, **113**, 34 and 39, 1823; *cf.*, *Observatory*, **38**, 292, 1915) thus summarized the situation in 1823: "In proportion as the instruments have been imperfect in their construction, they have misled observers into the belief of the existence of sensible parallax." The Greenwich instrument, with which he worked, proved to be more accurate than the others, whence he concluded "that this is the reason why it discovers no parallax at all."

But finally, independently and within a few months of one another, three apparently trustworthy parallaxes were published in 1838-9. They were all determined from observations with different types of instruments. Henderson's parallax for alpha Centauri, secured first but published third, was an "absolute parallax" determined from measurements made with a transit instrument and a meridian circle at the Cape Observatory for the purpose of obtaining a more accurate catalogue position for the star. F. G. W. Struve at Dorpat found a "relative parallax" for Vega from his double-star micrometer measurements of the distances of Vega from faint neighboring stars. Bessel's well-known determination of the parallax of 61 Cygni was likewise a relative determination, depending on similar measurements made with a divided objective (Fraunhofer's heliometer). But before discussing these three parallaxes let us first examine a few promising investigations that immedidately preceded these results.

The Dawn of Parallaxes. During the early years of the nineteenth century numerous attempts were made at determining parallaxes both from changes in the zenith distances of stars and from their times of meridian passage. It was hoped to find that the observed positions would oscillate slightly about their mean predicted positions with a period of a year. The apparent effect of the parallax could be somewhat enhanced by investigating not the individual positions as such, but the variations in the differences in right ascension of pairs of stars separated by about twelve hours, but observed within a few minutes of one another. A few results from this method that appeared slightly promising, though still far from adequate, are contained in Bessel's rediscussion of Bradley's observations made in 1750-61 ("Fundamenta Astronomiae," 1818). These results are compared with the modern Yale Catalogue values:

Stars	Diff. in R.A.	Parallax Equation	Modern Value
α Canis Majoris and α Lyrae	$11^h\,54^m$	$\pi + 1.227\pi' = 0''.044 \pm ''.243$	$0''.523$
α Canis Majoris and α Aquilae	$12^h\,12^m$	$\pi + 1.005\pi' = 0''.9313 \pm ''.2085$	$0''.584$
α Ursae Minoris		$\pi = -0''.1477 \pm ''.0802$	$0''.003$

The best observations of this sort were obtained by F. G. W. Struve at Dorpat between 1818 and 1821 (*Observationes Astronomicas*, **3**,

LXXXVI, 1821; *cf.*, also F. W. Dyson, *Observatory*, **38**, 292, 1915; J. Jackson, *Observatory*, **45**, 343, 1922). In choosing circumpolar stars he was enabled to observe at both upper and lower culmination, thereby availing himself of pairs with the maximum possible difference in parallax factor, which could, moreover, be observed within a few minutes of one another. Table II is a transcription of his results to-

TABLE II

F. G. W. STRUVE'S RELATIVE PARALLAXES, 1821

Stars		Equation	Modern Result	Diff./Error
π	π'			
Polaris	ϵ U Ma	$\pi + 0''.053\,\pi' = 0''.064 \pm .024$	0".043	1
ϵ U Ma	α Cas	$\pi + 0.962\,\pi' = -0.152 \pm .078$	0.081	3
ζ U Ma	δ Cas	$\pi + 1.099\,\pi' = 0.152 \pm .090$	0.077	1
β U Mi	α Per	$\pi + 0.402\,\pi' = 0.264 \pm .050$	0.033	5
α Aur	β Dra	$\pi + 1.147\,\pi' = 0.044 \pm .098$	0.081	1/6
β Aur	γ Dra	$\pi + 1.138\,\pi' = -0.073 \pm .083$	0.064	2
ζ U Ma	pr. et. seq.	$\pi - \pi' = -0.038 \pm .114$	0.0	1/3
δ U Mi		$\pi = 0.163 \pm .026$	0.010	6
ϵ U Mi	α Aur	$\pi + 0.191\,\pi' = -0.110 \pm .053$	0.147	5
α Cyg	ι U Ma	$\pi + 1.076\,\pi' = 0.434 \pm .066$	0.018	7
α Cep	η U Ma	$\pi + 1.073\,\pi' = 0.017 \pm .067$	0.095	1
β Cep	ν U Ma	$\pi + 0.689\,\pi' = -0.126 \pm .070$	0.030	2
η Cep	1 U Ma	$\pi + 0.992\,\pi' = -0.008 \pm .114$	0.075	1
γ Cep	λ Dra	$\pi + 0.687\,\pi' = 0.020 \pm .055$	0.077	2
β Cas	γ U Ma	$\pi + 0.913\,\pi' = 0.047 \pm .097$	0.084	1/4
β Cas	δ U Ma	$\pi + 0.997\,\pi' = -0.038 \pm .158$	0.116	1

gether with a comparison of the modern equivalent values. Most of the differences are under four times the probable errors determined by Struve. Obviously, although the old values differ greatly from the current ones, Struve's parallaxes do indicate the correct order of magnitude, and they are a decided improvement over the work that preceded his.

Assuming that all the parallaxes for the stars he investigated are equal, we find an average parallax of 0".03, in excellent agreement with present day results. While the order of magnitude of the parallaxes is well indicated, the method employed has, however, the disadvantage that one cannot find the actual parallax of either star of a pair.

Struve also compared the right ascensions of alpha with beta and gamma Aquilae. On the assumption of zero parallaxes for the latter two stars, he found a provisional parallax for alpha of $0''.181 \pm 0''.094$. The Yale Catalogue parallaxes for these stars are respectively 0".205, 0".077, and 0".018. I have never seen this particular result quoted. Its probable error is, of course, high in comparison with the parallax itself. On the other hand, the order of magnitude of the parallax compares as favorably with modern results as his later parallax for alpha Lyrae which has received great acclaim as one of the three "first" parallaxes, but which, despite its apparently small probable error of one tenth the parallax, nevertheless proved to be too large by nearly six times the indicated error.

Thomas Henderson's Parallax for α Centauri. It was not until near

the end of Henderson's stay at the Cape that he learned of the large proper motion of α Centauri, a motion which prompted him to suspect the star of having a perceptible parallax. Had he been aware earlier of its large motion he would have planned his observations more suitably for parallax determination. His first result, secured after his return to England, depended upon his measurements in declination only. They yielded a parallax slightly in excess of one second of arc. Guided to caution by the experience of others, who had found that results obtained from measurements in one coordinate were not generally confirmed by the results from the other coordinate, Henderson delayed the publication of his results until the right ascension observations being carried out by Lieutenant Meadows at the Cape became available. The two sets of results (Table III) indeed proved to be in agreement with-

TABLE III

HENDERSON'S PARALLAX OF α CENTAURI (*Memoirs, R.A.S.*, **11**, 61, 1839)

	α^1 Centauri	α^2 Centauri
Observations in R. A.	$0''.92 \pm .35$	$0''.48 \pm .34$
Direct Observations of Dec.	1.42 .19	1.05 .18
Reflected Observations of Dec.	1.96 .47	1.21 .64
Weighted Mean (Both components assumed at same distance)	$1''.16 \pm .11$	

in the accuracies of the observations. But meanwhile both Bessel and Struve had preceded Henderson in the publication of a reliable parallax. In passing, it is of interest to note that Henderson's precaution in checking the results from one coordinate by those from the other is a precaution rarely taken nowadays in photographic work. And when it is taken, the results are often more disappointing than were Henderson's. His differed within twice their probable errors. Several modern determinations, although intrinsically far more accurate, disagree by more than three times their apparent probable errors. The current value for the parallax of α Centauri (Schlesinger and Jenkins, "Catalogue of Parallaxes," Yale, 1935) is $0''.756 \pm .007$. In view of the fact that the observations utilized by Henderson covered a period of only one year (May, 1832, to May, 1833) and had not been especially designed for parallax computation, the agreement between the very first and the best recent determinations is remarkably good.

Struve's Parallax for α Lyrae. When absolute parallax methods had appeared to fail, both Bessel and Struve reverted to the differential method of Herschel. In 1837 in his "Mensurae Micrometricae," Struve had discussed the problem of the determination of parallaxes with extraordinary foresight. The stars most suitable for investigation, he pointed out, should be found among 1) the brighter stars, 2) the stars having the greatest proper motion, and 3) those double stars that showed the largest orbital motions for their apparent separations. It is perhaps regrettable that Struve himself chose alpha Lyrae (from group 1) for his first test case. Possibly his choice was guided by the fact that

α Lyrae had an optical companion only 40″ distant—an ideal comparison star. Bessel chose the second alternative, selecting the high proper motion star 61 Cygni (proper motion 5″ annually) in spite of its comparative faintness (fifth magnitude). Henderson's case quite fortuitously satisfied all of Struve's probable conditions for measurable parallax.

Both Bessel and Struve had this advantage over their predecessors, that their telescopes were equatorially mounted and equipped with driving clocks. In the focal plane of his "powerful" 9-inch Fraunhofer refractor, Struve had a "position micrometer"—two parallel spider threads whose distance apart could be altered by means of screws. The difference in the readings of the screw heads when the parallax star and the comparison star were successively bisected gave the separation of the two stars. Thus he measured the position of α Lyrae relative to the faint apparent companion on 96 nights between November, 1835, and August, 1838, and found a parallax of 0″.262 ± ″.025 ("Additamentum in Mensuras Micrometricas," 1840). This result does not compare as favorably with later determinations as does one of the other two first parallaxes (Table IV); on the other hand it should not be for-

TABLE IV

THE THREE FIRST PARALLAXES

Star	Observer	π	Yale Catalogue
α Lyrae	Struve	0″.262 ± ″.025	0″.121
α Centauri	Henderson	1.16 ± .11	0.756
61 Cygni	Bessel	0.314 ± .014	0.299

gotten, as J. Jackson points out (*Observatory*, **45**, 341, 1922), that Struve deserves probably more credit than his contemporaries in forcing the question of the finiteness of stellar distances to a positive answer. In addition to outlining future investigations of trigonometric parallaxes, Struve emphasized the value of "hypothetical parallaxes"* for those double stars whose orbits could be determined. His outline of the three criteria for promising objects for investigation differs little from the precepts for modern parallax programs. The main difference has been in the shift of emphasis from the bright stars, as practically all of them have now been examined. Had the major emphasis in the past century been diverted from the brightest stars to stars satisfying Struve's second and third criteria, early progress would have been more rapid.

The Heliometer† and Bessel's Success. Bessel's renowned first paral-

*The hypothetical parallax is

$$\pi = a/T^2M^{1/3}$$

where a is the semi-major axis in seconds of arc, T the period of revolution in years, and M an assumed mass in terms of the mass of the sun.

†General references on heliometers: Seeliger, "Theorie des Heliometers," Leipzig, 1877; L. Ambronn, "Handbuch der Astronomischen Instrumentenkunde," **2**, 554-562, 1899; "Handbuch d. Ast.," **2**, 635, 1931; Valentiner, "Handwörterbuch d. Ast.," **2**, pp. 4-27, 1898.

lax (*A. N.*, **16**, Nos. 365-6, 66, 1838) was determined from measurements made with a heliometer, an instrument invented for the purpose of determining the solar parallax. The lens, like Struve's famous objective, was constructed by Fraunhofer, although Fraunhofer himself did not live to see the actual completion of the instrument (1829).

The earliest type of heliometer consisted of two objectives with a common eyepiece, the two lenses being moved relative to one another in such a manner that the image of one limb of the sun, formed by one objective, would coincide with the opposite limb seen through the second object glass. From the separation of the lenses the apparent diameter of the sun was ascertained. This form of heliometer, first invented by Servington Savery in 1743, was neglected until its independent rediscovery by Bouger in 1748 (*Memoires de Math. et Phys. de l'Acad. Royale*, 1748, p. 25; *Traité d'Optique*, **35**, 1760; *Phil. Trans.*, **48**, 165, 1753; *cf.*, Seeliger, "Theorie des Heliometers," **2**, 1877). Although the instrument was called *heliometer*, because of its original purpose, it was adapted to the measurement of angular distances between other objects as well, and might better have been called *objective micrometer*. This early form of the instrument would not, however, have been serviceable in the measurement of close double stars or parallaxes relative to close optical companions; for the minimum separation of the two objectives set a fairly large lower limit to the separations that could be measured. This drawback was overcome in the form proposed by John Dolland: the divided objective or mirror (*Phil. Trans.*, **48**, 178 and 551, 1753) which was retained without much improvement until the time of Fraunhofer.

The heliometer Fraunhofer built for the Königsberg University was the first such instrument with achromatic lenses. While lenses of this type had already been discovered in 1733 by Chester More Hall, he "being indifferent to fame and profit" failed to make his discovery known (Agnes Clerke, "History of Astronomy in the Nineteenth Century," 112, 1902). The principle of achromatic lenses was rediscovered by Dolland in 1758, but nearly three quarters of a century passed before the first achromatic heliometer was built.

Another improvement in the Fraunhofer instrument was in making the screws by means of which the two halves of the objective were moved relative to one another serve as the scale to indicate the precise amount of the shift. Previously only linear scales had been used for this purpose. Inasmuch as the accuracy of the measurements depended on accurate, time-consuming determinations of the errors of the screws, it became the custom to investigate the errors of only one screw, and hence to move only one of the halves of the objective. Since the motion was always perpendicular to the focal axis of the fixed half, it developed that the two images secured from the two half-objectives were not in equally good focus. Bessel pointed out (*Astronomische Untersuchungen*, **1**, 123, 1841) that this defect could be overcome by giving the dis-

placed half a cylindrical motion; but this appears to have been difficult to put into effect. It was first accomplished in the Repsold heliometer installed at the Radcliffe Observatory at Oxford in 1849 (*Astronomical Obs.*, **11**, 1850).

From the time of Bessel's first determination of the parallax of 61 Cygni, the heliometer became, with a few exceptions, the favorite parallax instrument until the advent of photography. Otto Struve (*Mem. Ac. Imp. Sc. St. Petersbourg*, Ser. 7, Tome I, No. 1, 1854) indeed disputed the supremacy of this instrument for parallax purposes, contending that the method of measuring differences in declinations, using a firmly constructed instrument, is capable of a higher degree of accuracy than was likely to be obtained with the Königsberg instrument which was subject to considerable errors of "an unknown or only suspected character," especially when the distances to be measured were large. On the other hand, Struve's preferred method depended for its higher accuracy on a fairly symmetric distribution of comparison stars (not always attainable) as well as on having the comparison stars located within only a few minutes of the parallax stars. With the heliometer, separations up to 1° 52′ could be measured (Ambronn, *Handb. d. Ast. Instrumentenkunde*, **2**, 554, 1899). Struve's method, moreover, was not appropriate for stars near the ecliptic where the parallax factors in declination are negligibly small.

Astronomers had thus struggled for centuries before the first reliable parallax goal had been achieved. The series of measurements from which Bessel secured the first parallax of 61 Cygni in 1838 were distributed over a period of only slightly more than a year; outlines for favorable observing programs at that time look modern even now, a century later, and surely seemed adequate to encourage hope and effort for comparatively rapid systematic progress. Yet in the next fifty years only some fifty parallaxes were determined. Some of the best results of this era were obtained by Gill and Elkin at the Cape Observatory and at Yale. Rapid progress, however, came only after the application of dry-plate astro-photography to this problem.

Early Photographic Work. Almost twenty years before the use of the dry plate in photography, Lewis M. Rutherfurd of New York had obtained celestial photographs (1860-1877) by the more cumbersome wet-plate process. Later measurements of these early plates by Gould and by Reese and Jacoby (see John K. Reese, *School of Mines Quarterly*, **13**, No. 2, 1891) proved that photography was capable of yielding higher accuracy in parallax determinations than had been obtained from visual heliometer observations. While Gould had presented a paper at a meeting of the National Academy of Sciences as early as August, 1866, showing that his measurements on Rutherfurd's plates of the relative positions of stars in the Pleiades were in close accordance with Bessel's earlier values based on heliometer measures, it was

more than twenty-two years before Gould's paper was actually printed (*Memoirs, Nat. Ac. Sc.*, **4**, 173 and 193, 1888).

The first definitive proof of the value of photography for parallax work was published in 1886 when Pritchard at Oxford had analysed 200 plates on 61 Cygni. These yielded a value of 0".438, in good agreement with the best visually obtained value then available, 0".468 (Clerke, "History of Astronomy in the Nineteenth Century," 4th ed., 417, 1902). Kapteyn later (1891) demonstrated his enthusiasm for the photographic technique by proposing a "Parallax Durchmusterung" whose undertaking would require a total labor comparable to that expended upon the "Carte du Ciel" and which would eventually yield the parallaxes of 800,000 stars to an accuracy of $\pm$0".025. His plan did not call for a choice of specific parallax stars. Rather, he proposed measuring all stars in given regions; whence the nearby stars would automatically be discerned by their deviations from the average. In a paper published in 1901 (*Groningen Pub.*, No. 1) Kapteyn demonstrated for 248 stars photographed by A. Donner at Helsingfors the accuracy and feasibility of his plan. But the details of his method failed to inspire enthusiasm; for he proposed that each parallax region be photographed at three or four consecutive seasons of maximum parallax factor all on the same plate. This meant that after each exposure the undeveloped plates were to be stored in a dark place for about six months awaiting the next exposure. There were numerous obvious objections to the method and it was not widely applied. Russian observers tried it, and the results published by Kostinsky in 1905 (*Pub. de l'Obs. Cent. Nicolas, Serie II*, **17**, Part 2) indicated systematic errors due to the alteration of the latent image during the long storage of the plates between exposures.

Nevertheless in 1899 Frank Schlesinger (*Ap. J.*, **10**, 244) had advocated a similar observational procedure. He furthermore proposed a method for reducing the recorded intensity of bright parallax stars relative to faint comparison stars by staining a narrow strip of the emulsion to a pre-determined degree.

In 1903 Arthur R. Hinks and H. N. Russell (*M. N.*, **65**, 775, 1905) began an investigation of stellar parallaxes at Cambridge, England. Enumerating the disadvantages of Kapteyn's method, they embarked upon an observational program and procedure whose major features differ but little from current practices. They did, however, impress a standard reseau on each plate to guard against errors that might arise from film distortions affecting large areas of the plate, a procedure later found to be unnecessary. Russell and Hinks planned for two or three plates at each epoch and experimented with a color screen to reduce the magnitude of the bright parallax stars to near equality with the faint comparison stars. A three millimeter square film of gelatin dyed deep orange was found to reduce a star's magnitude by as much as six magnitudes. Hour angle errors, effects of refraction, and guid-

ing errors were discussed. The first two parallaxes published were for Lalande 21185 and γ Virginis (Russell, *M. N.*, **65**, 787, 1905). The completed results for 52 parallax stars with detailed discussion of policy and procedures was published by Russell in 1911 (*Carnegie Institution of Washington,* Pub. No. 147). These results may well be considered among the first "modern" parallax determinations. In his discussion of the results, Russell computed the absolute magnitudes of the stars and grouped them according to spectral class, apparent magnitude and proper motion. Although this contribution does not give a plot of spectral class and absolute magnitude, the discussion clearly indicates the "Russell Diagram." Its possible bearing on stellar evolution is also considered. The Russell Diagram as such (based on these as well as on numerous other determinations of parallax) made its official appearance at a meeting of the Astronomical and Astrophysical Society of America on December 30, 1913 (POPULAR ASTRONOMY, **22**, 275, 1914).

Meanwhile fairly complete accounts of Schlesinger's pioneering use of the Yerkes 40-inch refractor for parallax work from 1903 to 1905 were appearing in the *Astrophysical Journal.* He, too, had abandoned the plan of storing exposed plates between parallax epochs. Moreover, he felt dissatisfied with his scheme of desensitizing the area of the film to be exposed to the parallax star, or of using minute color filters over a small area of the plate to reduce the density of the images of the bright stars. Since different stars had to be cut down by different magnitudes, these procedures did not permit easy variation from exposure to exposure. He therefore devised a rotating disc with adjustable sector-opening to be placed directly in front of the photographic plate at the position of the image of the bright star. As the disc rotated, it periodically occulted the bright star whose effective exposure then depended on the size of the sector opening.

With improvements introduced by Schlesinger early in this century, the evolution of the observational procedure in parallax determination is essentially complete. Further improvements were in detail and refinement but not in fundamental procedure. A paper by Schlesinger in the *Seeliger Festschrift* ("Probleme der Astronomie," p. 422, 1924) is still the best overall discussion of modern procedure and analysis of sources of errors in trigonometric parallax determinations. To Schlesinger probably more than to any one other individual we owe tribute for the large increase in the numbers and quality of trigonometric parallax determinations within the past fifty years.

A summary of the acceleration of progress since the first successful results is given in Table V (based in part on Lundmark, *Handbuch d. Astrophysik*, **5**, 431, 1932). From an average of less than one parallax a year one hundred years ago, to half a dozen half a century later, the rate in 1930 had risen to 500 for all varieties of determinations or to about 160 for trigonometric parallaxes alone (exclusive of redeterminations or duplicate measures at different observatories). At the same

TABLE V

PROGRESS IN THE DETERMINATION OF PARALLAXES

Year (t)	Δt	No. Parallaxes (N)	ΔN	Av. Annual Increase	Note
1838		3			
	44		31	0.7	
1882		34			
	10		53	5	
1892		87			
	18		278	15	
1910		365			
	14		1505	108	
1924		1870			All but about 200 trigonometric
	11		5664	515	
1935		7534			About 50% trigonometric

time the accuracy of the results also was showing conspicuous improvement with the changes in technique. The mean error for a single parallax was 0″.040 to 0″.060 from meridian circle observations; 0″.025 to 0″.040 for heliometer determinations; about 0″.017 for the early photographic results; and better than 0″.010 for the trigonometric parallaxes given in the 1935 Yale Catalogue of Parallaxes.

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASS.

Radio-Astronomy*

A New Science in Manchester

By BERNARD LOVELL

With its overcast skies and smoke, Manchester, England, could scarcely be regarded as a paradise for astronomers, yet the University has been bold enough to take a pioneering share in founding a new branch of astronomy. The radio techniques which enabled our bombers to see the Tempelhof aerodrome through ten thousand feet of mist and cloud in 1943 have now been deployed in reverse. The effects of a minute piece of stone burning away in the earth's atmosphere 60 miles up can now be studied however thick the cloud, and at the University research center at Jodrell Bank in Cheshire records are regularly made of particles smaller than a pin's head which enter our atmosphere over the Atlantic Ocean.

On a clear moonless night these shooting stars, or meteors, can be seen with the naked eye, but hitherto the study of these effects has been largely a spare-time amateur activity. The limitations of naked-eye observation with its dependence on a dark clear sky presented great obstacles to systematic advance, and in spite of much work in Britain and in America the subject remained a cinderella in astronomy.

But, like so much in science, all this was changed by war. When the V2 rocket bombardment of London began, every method of giving

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warning of even a few seconds was explored. Among these, radar equipments used by A.A. Command were modified in the hope that the rockets would give a transient radar echo as they traveled high up in the atmosphere. They did, but it was soon found that short-lived echoes were obtained and warnings given when no rockets were about. These spurious echoes were studied by J. S. Hey and his colleagues in the Army Operational Research Group, who eventually concluded that they were caused by meteors in the earth's atmosphere.

The Meteor Streams

About a dozen showers or streams of meteors can be recognized by the visual astronomers. These meteor streams are great areas of minute debris moving under the influence of the sun like the earth or planets. When the earth crosses one of these orbits the small pieces of stone and iron rush into the atmosphere at enormous speeds. They get hot by friction and burn away 60 miles up in the atmosphere—producing the familiar streak of light. As well as this visible trail, the meteor also leaves behind a dense trail of electrons. It is these electrons—existing in many cases only for a fraction of a second—which send back the radio waves to earth and so enable the meteors to be observed under all conditions—including cloud or daylight.

It was this ability to study meteors in daylight which soon led to a remarkable discovery. On May 1, 1947, the equipment at Jodrell Bank was directed to study a meteor stream known to the astronomers as the eta-Aquarids. Existing information about this stream was not very detailed, since it does not rise above the horizon until after midnight and dawn soon interferes with the observations. It was believed to be quite a small stream—giving about ten meteors an hour to a naked-eye observer—and lasting for about a week, by which time the earth would have swept through this particular stream of debris and nothing more could be seen for another year. It was also believed to be fairly isolated in space—in fact the astronomers' lists did not indicate another shower until late July.

The observations on May 1 at Jodrell Bank showed that this eta-Aquarid shower was by no means isolated, but that it was followed some three hours later by a very vigorous meteor stream hitherto unobservable because of daylight. It was immediately followed by other showers of even greater intensity, and by mid-June the day-time sky was evidently a blaze of meteoric trails. These great series of showers continued right through the summer until the end of August.

Apparently in early May the earth began passing through a vast area of debris in space so extensive that it was four months before it emerged. The advent of the spring of 1948 was eagerly awaited. Would these phenomena be repeated? They were—with striking resemblance to 1947. Perhaps for hundreds or even thousands of years this prolonged celestial display has occurred, but not until 1947 did man have eyes with which to see it.

100,000 Miles an Hour

To measure a speed of 100,000 miles an hour, especially of something which appears without warning and is gone in less than a second, is no easy task. In fact, only a few accurate measurements of the speed of these meteoric particles existed—and these were primarily due to the beautiful photographic work of Dr. F. L. Whipple, of Harvard Observatory. The magnitude of the task is indicated by the fact that it took Dr. Whipple five years to collect nine precision measurements of the speed of the meteors of the Geminid meteor shower which occurs in December every year.

In October, 1946, Hey discovered that a few of his photographs of the radio echoes from the great Giacobinid meteor shower gave enough information for him to calculate how fast these meteors were moving. Just over a year later at Jodrell Bank, after a prolonged effort, two of the scientists succeeded in making the radio echo from the meteor operate an automatic recording device, which gave the history of the meteor every thousandth of a second as it swept through the aerial beam. During two December nights of extremely thick fog they measured the speed of over thirty Geminid meteors—and their measurements were in precise agreement with those of Dr. Whipple.

No one yet knows whence these vast numbers of meteoric bodies come. From the observations on the night-time showers, it seemed likely that the meteor streams were closely associated with comets, and although the new results are not yet assimilated it already looks as though new evidence will be provided in favor of this idea. It may well be that the astronomers will soon be able to place meteors and comets more satisfactorily in the evolutionary framework of the solar system, and then we shall know whether these strange bodies represent the primeval matter or the final disintegration of our near neighbors in space.

Scientists can now study the strange radio waves which originate in the depths of space and reach the earth after traveling on their journey with the speed of light for 100,000 years. At Jodrell Bank the radio equivalent of a giant telescope collects these radio waves from a small region of space, adding to the steadily accumulating store of knowledge from many parts of the world which may one day tell us exactly where these emissions originate—stars, remote nebulae, or interstellar space.

This work at Jodrell Bank has been possible not only through the sustained efforts of the small group of scientists privileged to work there but also because of the great help and foresight of the University authorities. In December, 1945, Professor P. M. S. Blackett gave every possible encouragement and help to the initiation of a scientific enterprise, remote from his laboratory, which many would have dismissed

as beyond hope. The Vice-Chancellor and Council of the University soon followed this act of faith by others, and have thereby given to Manchester a unique place in a rapidly growing new science.

An Unused 62-inch Mirror*†

By PRISCILLA BIRON WOOD

With the new telescope on Palomar Mountain already disclosing more wonders of our universe, we are reminded of another, not quite so large or so carefully made as the 200-inch mirror. There is a mirror, 62 inches in diameter, which was made more than 50 years ago by 77-year-old John Peate, a retired Methodist minister. It was finished in 1897 and remained the largest completed *glass* mirror in the world until 1917 when the Dominion Observatory's 72-inch was erected in Victoria. Unfortunately, Peate's mirror has never been mounted, and is now resting idly in a back room at the Smithsonian Institution in Washington, D. C., where it has been on loan these past 15 years. The mirror belongs to the American University in Washington, D. C. It was given to the University by its maker, the cost, $450, of casting the disc being borne by the Methodist-Episcopal Erie Conference, of which Peate was a member.

It is said that Peate was about to be superannuated at a meeting of the Erie Conference in Dubois, Pennsylvania, in 1893, and that he was anxious lest this event might make him suddenly useless to the world, and so he asked his Bishop what he should do the rest of his life. The Bishop suggested that he study astronomy, and build a big telescope. He gave Peate a pamphlet telling him how to go about it. Peate then announced to the gathering that, providing it would defray the expenses involved, he would make the world's largest telescope mirror for the American University. The presiding Bishop, who was also Chancellor of the University, asked how big it would be, and Peate answered, "Oh, as big as that map on the wall," whereupon Chancellor Hurst asked that the map be measured. It was found to be 62 inches wide.

This story, although more colorful than the truth, does an injustice to the real forethought and work of the Reverend Mr. John Peate, D.D., of Greenville, Pennsylvania. Actually, he had been making telescopes for some 16 years before this. His original interest had, however, sprung from his concern over what to do after being superannuated, and a colleague had suggested telescope-making as a good project for his old age. Peate had already finished at least 14 mirrors,

*Acknowledgement is gratefully given for the suggestions and information received from Dr. Charles H. Smiley, Dr. John Hall, Dr. James G. Baker, and Dr. George W. Morey, and for the records made available by the American University and the Smithsonian Institution.

†Persons interested in this mirror should communicate with Dr. Paul F. Douglass, President, American University, Washington, D. C.

and possibly one refractor, ranging in size from a 3-inch to a 30- or 36-inch, before attempting the 62-inch.

Many of Peate's mirrors are still in use today. His second was a 7-inch which was sent to missionaries in India and mounted there by the British Government, where it may still be in use. One of his mirrors, made of flint-glass, and used in his private observatory in Greenville, was later sent to the Hoyt Observatory, Salina, Kansas, but its present whereabouts is unknown. The 15-inch mirror at Allegheny College, Meadville, Pennsylvania, is also thought to be Peate's, and a 22-inch at Thiel College, Pennsylvania, is definitely known to be one of his.[1]

For his early mirrors, Peate had obtained his glass from St. Gobain, France, the famous glass works which cast Mt. Wilson's 60-inch and 100-inch, as well as the Dominion Observatory's 72-inch, just prior to being destroyed by fire during World War I. For the glass for his greatest undertaking, Peate again wrote to the French firm, but upon hearing its price, $18,000, he turned for the first time to American glass manufacturers, only to find that the established firms would not accept such a task. Finally in Butler, Pennsylvania, at the new Standard Plate Glass Company, was George Howard, a recent Cornell graduate who had not yet come face to face with the problems involved in such an undertaking as the casting of a 62-inch blank. But amidst the slanderous writings of rival glass companies, who published the statement that "no one but a superannuated, itinerant preacher would have thought of going to Butler County to cast a lens," the 2,500 pound disc was successfully cast on the third trial, annealed in 11 days, and presented to Peate on May 4, 1895, for a total cost of $450. Howard has since freely said that his was a case of "fools rush in where angels fear to tread," and has ascribed his winning combination to be a mixture of "ignorance and lady luck."

The general belief of more established glass companies at the time was that the casting of such a large telescope blank could not be done in America, and their publications ridiculed the Butler firm for attempting such a hopeless task. It wasn't until 32 years later that another disc of such size was cast in America, this one being the 69-inch cast by the National Bureau of Standards in 1927 for the Perkins Observatory at Ohio Wesleyan University. Thus the successful pouring of Peate's mirror marked a great forward step in American glass-making history.

Peate worked two years grinding and polishing the mirror, using a device constructed for the purpose, and set up in a special long-corridor shed that he had built in an old cow pasture in Greenville. Because of the great effect of heat and cold on the glass, and because he could not heat his workshop uniformly, he found that he could work only in the spring and autumn. Peate wore a long beard, and it is said that one of his means of testing the mirror was to pull one hair from his beard, put it on a distant fence, and examine it with his telescope.

In 1897, Peate shipped his mirror to the American University which

was still new and struggling for adequate funds. The University appealed again and again for financial help to mount the telescope, but the appeals went unheeded, and for more than 30 years the glass stood next to a radiator in Hurst Hall on the University campus. Finally, in 1934, it was loaned to the Smithsonian Institution, and was placed, still standing on edge in its glass case, on public display.

Peate's 62-inch is an unsilvered mirror about 6 inches in thickness and having a focal length of 32.3 feet. The surface of the glass is relatively free of scratches and the job of polishing appears to have been well done. The glass contains very few bubbles, and none are near the surface. This mirror was recently subjected to a Foucault test by one whose previous experience had been limited to amateur mirror sizes. The test was intended only to give a rough idea of how completely Peate had figured his mirror, and to determine its approximate focal length, given above. The equipment used was a makeshift apparatus consisting of a coffee-can, complete with light and pin-hole, and an ordinary razor blade, mounted so that it could be moved in the two necessary directions. Since it was to be only a rough test, no preparations were made for air-conditioning the testing room, which, for an accurate test, would be necessary with so large a mirror.

Imagine, if you can, walking 64 feet from your mirror before setting up your Foucault apparatus! You look for the light reflected from the coffee can's pin-hole, and are momentarily blinded when it suddenly strikes your eye. You push the razor blade over to pick up the shadows, and are startled to see shadows jumping all over the mirror, continually moving. Then you suddenly wonder if the heat radiating from another person standing a few feet away from the mirror is affecting the figure. He moves away and the shadows become a bit calmer, but you realize that the imperceptible air-currents in the room, and even your own breathing, are greatly influencing the shadows you are trying to measure, and it becomes even more apparent to you what a tremendous undertaking the making of a large telescope becomes.

The separation of the focal points of various zones on the mirror's surface was so slight, and under the adverse conditions, so inaccurate, that no attempt was made to compute the figure of the mirror. The appearance of the shadows, however, would suggest that Peate had slightly over-corrected a parabolic figure. Except for this and whatever tests Peate must have made, the mirror has never been tested for its figure. In the early 1920's, however, F. W. Fecker examined the mirror for annealing and found that it showed much asymetrical strain, technically known as birefringence, and, on the basis of his findings, did not recommend that this mirror be used by the Ohio Wesleyan University, but suggested the casting of another disc for its purposes. Later, during the winter of 1934-35, tests for strain were conducted by Wright and Morey of the Geophysical Laboratory, Wash-

ington, D. C., who agreed with Fecker that the glass was not well annealed by present optical standards.

However, before beginning to work on the blank, Peate had trimmed it to a perfect circle by chipping its edges with a hammer. Since polariscopes were not used by American glass companies in his day, Peate could rely only on the belief that if the mirror could withstand the blows of a hammer, it must be satisfactorily annealed in a mechanical sense.

The effect of this poor annealing in ordinary usage would be likely to produce stray brushes of light at or near the focus, or to make a star look like an elongated ellipse, a defect which would show up far worse while the mirror was cooling down.[2]

Another problem involved in using this mirror is its thickness. Ritchey has stated[3] that the ratio of the thickness of the mirror to its diameter must be at least 1:12 in smaller mirrors and should be 1:7 or 1:8 for larger mirrors. The ratio for Peate's mirror is scarcely 1:12. However, Harvard University operates two large telescopes, one a 60-inch, and the other a 61-inch, both made by Dr. Common in England, the glass having been made at the St. Gobain Works in the late 1880's. Both of these are about 5 inches thick, and both still in use, one at Oak Ridge, Massachusetts, and the other in South Africa. It has proved possible to figure the South African mirror, for example, from night to night by adjustment of the counterweights and star Foucault test at the Newtonian focus. The larger mirrors are very flexible and it is alweays necessary to have a suitable support system with counterweights.

It must also be remembered that the invention of ribbed, borosilicate, or Pyrex, mirrors, which do not respond to temperature changes as readily as soda-lime glass mirrors do, places another disqualifying blow on Peate's mirror for use in precision work.

Finally, since the cost of an observatory dome and mounting may be estimated at approximately 10 times the cost of the mirror, it would not be wise to mount a long focal-length mirror with so many undesirable features. However, to the casual observer, it would seem that somewhere in the scientific world, there would be a use for this mirror.

In 1934, the American University offered the mirror as a gift, to the National Bureau of Standards for the purpose of testing "cold flow," since the mirror had been resting in the same position for nearly 40 years. The Bureau had to refuse the offer on the grounds that its optical and astronomical interests were not sufficient to justify the expense involved in mounting it. It may be noted that in the Foucault test recently conducted, no effect of "cold flow" was evident.

David Todd, formerly professor of Astronomy at Amherst, had planned to take the mirror with him on an expedition to South America to take motion pictures of Mars, but found he could not use it. It has been suggested that if the mirror were used in only one position, there-

by avoiding excessive strain, it might work satisfactorily, particularly if used photoelectrically, since a large light-gatherer of inferior quality can often serve reasonably well in photoelectric work. The blank might also be used as a grinding tool for full-size grinding and polishing of a large Pyrex mirror, although metal tools are nearly as good.

It has also been suggested that the glass be reannealed and dropped on a spherical plate for a Schmidt telescope, but this constitutes practically re-making the entire mirror, and the user would undoubtedly benefit by using a fresh Pyrex blank. The mirror might also be refigured and used photoelectrically as a flat mirror in a polar mounting where the light is reflected up an incline to a smaller paraboloidal reflector in a fixed mount. The light reconverges to a hole in the flat to a photoelectric photometer. Possibly an amateur telescope makers' club might enjoy using the mirror in this way. Perhaps the only and best use for this mirror is for it to remain in the Smithsonian Institution for its historical interest, since it was the first large blank to be cast in America, and was cast 32 years before another similar attempt was made in this country.

The mirror might even be melted and made into windowpanes, but whatever its use, we cannot forget the white-bearded old man, perched high on a special ladder, high enough to put him at the mirror's focus, using his own telescope, and discovering that even though "it was able to resolve the star dust of the Milky Way into separate stars, there was still a Milky Way beyond."

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52 W. 102ND ST., ORANGEBURG, NEW YORK, MARCH, 1949.

The Knowledge of the Astronomer

By A. FORREST STEEPLETON

Unquestionably the modern astronomer has gone far, in accumulating knowledge of the cosmos, over any other age in the history of men. Before the year 1609 A.D. but little was known of astronomy except a meager bit of learning which centered about the solar system. But now with the great telescopes of the observatories knowledge has indeed increased until astronomy has become a major science in the world.

Today the astronomer knows more about the Milky Way galaxy than ever before, and a great deal more about it than anyone else, for that object of the heavens has become one of his most intimate studies.

He knows that it is made up of a great number of heavenly bodies of very different types, a part of which is an aggregate of a hundred billion suns, according to the Harvard Professor, Dr. Harlow Shapley.

Moreover in all that vast number of stars no two of them are exactly alike in every particular. For instance, some suns are a hundred times greater in mass than our sun, and others radiate ten thousand times more light, nevertheless our sun is an excellent representative body of the galaxy. In fact the new book "Astronomy" written by William T. Skilling & Robert S. Richardson states that advanced knowledge reveals that our sun is a little above the average one in mass and luminosity of all the other stars within the galaxy. It is also classified as a main sequence star in the Russel diagram and is grouped there among the finest specimens of the yellow class G suns.

It is also known that the stars of the Milky Way galaxy are not of the same age. For some of them are very young in comparison to others, and some are very old. In respect to the young suns that are just beginning their life among the other stars they do present a difficult problem to the thinking astronomer as he considers them. They seem to form and develop out of the loose material of the elements of matter that exist at present in ample abundance in interstellar space. And there is no doubt but that they will continue to form as long as there is a sufficient amount of stellar dust and gas left in the galaxy to produce them. Eventually, however, that extra matter will be exhausted and then there will be no more new suns developed. It seems as though there is a natural law in existence within the heavens which is the deciding factor as to the number of stars that will accumulate within a galaxy jut as there is a law of nature which predetermines an approximate number of roses to every rosebush, or red cherries to a cherry tree, and no more.

Then too, there is the question of age and color. Young stars are very red in their infancy. Their color also indicates their temperature. The red suns are the coolest ones but as they advance in age their color changes as their temperatures increase. Some stars without doubt will run through the whole gamut of all the colors of the rainbow during their lifetime. Others probably do not, since it is hardly possible for all stars to pass through the same identical cycle of life in every particular when there is such a diversified classification of celestial bodies.

The very old stars also present a problem of deep concern particularly as to the state of the elemental matter of which they are composed. For instance, one cubic inch of it will weigh as much as a ton or more of iron on the earth. And yet that matter is the same sort as that we are perfectly acquainted with. We know that everything in the entire universe of matter or everything inanimate in all the cosmos is composed of the 92 elements of the periodic table together with their isotopes in molecular form. But we are not altogether familiar with all forms that

by avoiding excessive strain, it might work satisfactorily, particularly if used photoelectrically, since a large light-gatherer of inferior quality can often serve reasonably well in photoelectric work. The blank might also be used as a grinding tool for full-size grinding and polishing of a large Pyrex mirror, although metal tools are nearly as good.

It has also been suggested that the glass be reannealed and dropped on a spherical plate for a Schmidt telescope, but this constitutes practically re-making the entire mirror, and the user would undoubtedly benefit by using a fresh Pyrex blank. The mirror might also be refigured and used photoelectrically as a flat mirror in a polar mounting where the light is reflected up an incline to a smaller paraboloidal reflector in a fixed mount. The light reconverges to a hole in the flat to a photoelectric photometer. Possibly an amateur telescope makers' club might enjoy using the mirror in this way. Perhaps the only and best use for this mirror is for it to remain in the Smithsonian Institution for its historical interest, since it was the first large blank to be cast in America, and was cast 32 years before another similar attempt was made in this country.

The mirror might even be melted and made into windowpanes, but whatever its use, we cannot forget the white-bearded old man, perched high on a special ladder, high enough to put him at the mirror's focus, using his own telescope, and discovering that even though "it was able to resolve the star dust of the Milky Way into separate stars, there was still a Milky Way beyond."

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52 W. 102ND ST., ORANGEBURG, NEW YORK, MARCH, 1949.

The Knowledge of the Astronomer

By A. FORREST STEEPLETON

Unquestionably the modern astronomer has gone far, in accumulating knowledge of the cosmos, over any other age in the history of men. Before the year 1609 A.D. but little was known of astronomy except a meager bit of learning which centered about the solar system. But now with the great telescopes of the observatories knowledge has indeed increased until astronomy has become a major science in the world.

Today the astronomer knows more about the Milky Way galaxy than ever before, and a great deal more about it than anyone else, for that object of the heavens has become one of his most intimate studies.

He knows that it is made up of a great number of heavenly bodies of very different types, a part of which is an aggregate of a hundred billion suns, according to the Harvard Professor, Dr. Harlow Shapley.

Moreover in all that vast number of stars no two of them are exactly alike in every particular. For instance, some suns are a hundred times greater in mass than our sun, and others radiate ten thousand times more light, nevertheless our sun is an excellent representative body of the galaxy. In fact the new book "Astronomy" written by William T. Skilling & Robert S. Richardson states that advanced knowledge reveals that our sun is a little above the average one in mass and luminosity of all the other stars within the galaxy. It is also classified as a main sequence star in the Russel diagram and is grouped there among the finest specimens of the yellow class G suns.

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The very old stars also present a problem of deep concern particularly as to the state of the elemental matter of which they are composed. For instance, one cubic inch of it will weigh as much as a ton or more of iron on the earth. And yet that matter is the same sort as that we are perfectly acquainted with. We know that everything in the entire universe of matter or everything inanimate in all the cosmos is composed of the 92 elements of the periodic table together with their isotopes in molecular form. But we are not altogether familiar with all forms that

matter may be in. Indeed it would be an interesting experience to examine closely the mysterious ionized elements of a white dwarf sun.

But of all the stars within our galaxy the sun is the most intriguing one to the modern astronomer. Furthermore he has given it more intense study than any other heavenly body either celestial or terrestrial. Moreover he knows that it was not the first sun to be created and to shine within the Milky Way galaxy. And he derives that information from the fact that there are many suns visible in the heavens that are vastly older than our sun by the factor of millions of years; suns grown hoary with age, that are on the way to extinction. Dying suns that are fading away forever.

Most scientists agree pretty well about the probable age of the sun. They say that it is from two to three billions of years old. They do, however, have a better knowledge as to the way it derives its tremendous energy to light and sustain the planetary bodies that move so gracefully around it from age to age. They also know that it is losing its mass by radiation at the unbelievable rate of 5 million tons a second, and that at some far away period of the future ages it will end in death by nucleonic disintegration.

Furthermore the investigations of the astronomer are not wholly confined to the solar system and the Milky Way galaxy in which we find ourselves revolving in space. But he also interests himself in other astronomical object that adorn the heavens. For far out in the unending reaches of the eternal void exist other galaxies beside our own. They are called extra-galactic nebulae. Some would rather call them extra-galactic universes. Nevertheless they are galaxies and every whit as large as our own. That is, some of them are, and some are probably larger. However, they all go to make up the universe of matter, and constitute our neighbors of space. Most of the galaxies incidently, are removed from us by the distance of millions of light years (a light year is the distance that the energy of light will travel in 365¼ days, or a year, travelling at the terrific speed of 186,300 miles a second, or equivalent to 6 trillion miles). One may ask the question, just how many galaxies occupy the space of the heavens? The answer is, nobody knows. But the most powerful telescopes can resolve a hundred million. But that is not the end of the galaxies. Moreover as the astronomer points his telescope towards the heavens and seeks the farthest frontier of the galactic empire, he can discern the light coming from some galaxies so distant that it has taken their light 500 million years to reach the earth.

Now as the astronomer considers the galaxies as astronomical units in space he can see that they do change their form and shape and pattern constantly. And that they have a definite lifetime as do the stars that compose them. But no human mind as yet has been able to tell us the length of that tremendous span of measurable duration.

Nevertheless they all go through a certain life cycle. A young galaxy

will possess a form that is unquestionably youthful to the eyes of one who is familiar with them. Moreover there is a steady advancement to a definite maturity, and when it reaches that apex of its life it is the most awe-inspiring of its whole existence, presenting a truly commanding figure in space. A dynamic thrilling picture of swirling suns in motion. And what a motion it is, providing one can imagine seeing a hundred billion stars grouped in one great body turning like a giant wheel in space circling at a speed of from 175 to 200 miles a second.

Our sun and planets are located about 30,000 light years away from the hub of the galaxy or about two-thirds of the distance from the hub to the outer rim. The diameter of the galaxy is approximately 100,000 light years. And it is probably 10,000 light years thick. Moreover when our solar system has made but one turn completely around with the galaxy, 250 million years have rolled away, so great, and so vast, is the sweep of our mighty galaxy.

Again, as has been said before, every galaxy in the metagalactic cosmos will eventually grow old. And when they do so they present a very different picture in space from that when they were young. And when the gazer of the stars recognizes them he is amazed at the great change that has taken place in them. For their early beauty is gone. They have lost the symmetry of their proportions. Their arms are gone or bent or broken. And their bodies are falling apart as though torn by a mighty wind, and every part of them is a picture of utter dissolution.

But here and there still burn and shine some of the great supergiant suns, the last born monarchs of a mighty host that has preceded them in death. But eventually they too will join the others in the cemetery of the skies.

Thus as the astronomer views the heavens and ponders there the great drama of inanimate matter as it unfolds itself before him in a panoramic picture of birth and death, he is made to recall the words of the Hebrew author who wrote—AND THOU LORD, IN THE BEGINNING HAST LAID THE FOUNDATION OF THE EARTH: AND THE HEAVENS ARE THE WORKS OF THINE HANDS: THEY SHALL PERISH: BUT THOU REMAINEST: AND THEY ALL SHALL WAX OLD AS DOTH A GARMENT: AND AS A VESTURE SHALT THOU FOLD THEM UP, AND THEY SHALL BE CHANGED: BUT THOU ART THE SAME, AND THY YEARS SHALL NOT FAIL.

4305 BERKELEY AVE., CHICAGO, ILLINOIS.

Mean New Moons

By R. B. WEITZEL

The term "mean new moon" is in well-established usage in astronomy to denote the circumstance in which the mean longitudes of the sun and the moon are equal, *i.e.*, when the mean elongation $D = L_{moon}$

— L⊙ is zero. To illustrate: the *American Ephemeris* for 1940 gives on page 653 the mean longitude of the moon at 10-day intervals, and on page 18 the mean longitude of the sun at 5-day intervals. Lesser periods, such as minutes and seconds, not supplied in the *Ephemeris*, can readily be figured.

Mean Longitude of Moon		Mean Longitude of Sun	
1940 I 2, 0^h GCT	184°.1813	1940 I 6, 0^h GCT	284°.4397
7^d	92.2347	3^d	2.9569
I 9	276.4160	I 9	287.3966
21^h	11.5293	21^h	0.8623
37^m	0.3386	37^m	0.0253
2^s	0.0003	2^s	0.0000
	288.2842		288.2842

In the example the mean longitudes of the sun and the moon are equal, thereby denoting the occurrence of a mean new moon: 1940, January 9, 21^h 37^m 2^s GCT. The corresponding Julian day number to four decimals, measured from Greenwich midnight as zero decimal, is 2429638.9007.

Another example computed from mean longitudes of the sun and the moon in the *American Ephemeris* for 1948 will be given.

Mean Longitude of Moon		Mean Longitude of Sun	
1948 IV 29, 0^h GCT	280°.4275	1948 V 5, 0^h GCT	42.7789
9^d	118.5876	3^d	2.9569
V 8	39.0151	V 8	45.7358
13^h	7.1372	13^h	0.5339
13^m	0.1190	13^m	0.0089
52^s	0.0079	52^s	0.0006
	46.2792		46.2792

A mean new moon occurred: 1948, May 8, 13^h 13^m 52^s GCT, or Julian day number 2432680.5513.

The Greenwich civil or universal time of the mean new moons can be derived directly from E. W. Brown's *Tables of the Motion of the Moon*.

Constant	15.5000		
1940 I 1	— 6.5993		
I 1	+ 8.9007	1940 I 9.9007 GCT, or 2429638.9007	
Constant	15.5000		
1948 I 1	— 5.0711		
I 1	+10.4289	1948 I 11.4289 GCT, or 2432562.4289	
		4 lunations	118.1224
		1948 V 8.5513 GCT, or 2432680.5513	

Approximate mean new moons to two decimals are deducible from the lunar tables of Schram (1908), by substituting the constant 0.61 for the values of a and b, as exemplified:

2427305.37			2427305.37		
2332.92			5374.57		
0.61			0.61		
2429638.90	1940 I	9.90	2432680.55	1948 V	8.55
Brown	1940 I	9.9007	Brown	1948 V	8.5513

Some comparative examples of mean new moons, derived from the tables of Brown and Schram, respectively, are listed.

		Brown	Schram
420	I 1	1874463.8133	1874463.80
	IX 23	729.5886	729.58
421	I 19	847.7109	847.70
	IV 18	936.3027	936.29
820	I 19	2020581.1774	2020581.17
	IX 11	817.4221	817.41
821	I 7	935.5444	935.54
	IV 6	2021024.1362	2021024.13
1220	I 7	2166669.0067	2166669.00
	IX 28	934.7820	934.78
1221	I 24	2167052.9043	2167052.90
	IV 23	141.4961	141.49
1620	I 4	2312756.8317	2312756.83
	IX 26	2313022.6070	2313022.61
1621	I 22	140.7293	140.73
	IV 21	229.3211	229.32
1920	I 20	2422344.8455	2422344.84
	IX 13	581.0902	581.09
1921	I 9	699.2125	699.21
	IV 7	787.8043	787.80

The interval between the mean new moon of April 7, 1921, and the mean new moon of May 8, 1948, is 29.530588×335, or 9892.7470 days.

426 Bond Building, Washington 5, D. C.

An Apparent Occultation of a Star by a Jovian Satellite

By WALTER H. HAAS

Not many observers have ever witnessed an occultation of a star by a planet, and an occultation of a star by one of the four bright satellites of Jupiter must be an event considerably more infrequent still. What appeared to be just such an occurrence was observed by the writer, Director of the Association of Lunar and Planetary Observers. He used a 6-inch reflector at 188x in Albuquerque, New Mexico, U.S.A., on April 12, 1949. The seeing was somewhat poor; the sky was extremely clear. Jupiter was seen well enough that five belts were revealed. A record of the observation follows. All times are by Universal Time.

$11^h\,4^m$. A star estimated to be of the ninth magnitude was noted only 2″ or 3″ east of Jupiter II. (As regards the star's brightness, it was later still barely visible at $12^h\,23^m$, only 16 minutes before sunrise.) Since Jupiter was moving eastward and since the satellite was moving eastward relative to Jupiter supposed at rest, it was realized that an occultation might be imminent.

$11^h\,12^m3$. The star was seen, and the distance between the centers of the discs was estimated to be perhaps 1″5.
$11^h\,13^m6$. The star was seen with difficulty.
$11^h\,15^m0$. The star caused the satellite to look elongated.
$11^h\,16^m6$ to $11^h\,23^m9$. The star was invisible.
$11^h\,25^m5$. The star was seen with difficulty to the west of the satellite and perhaps 1″ away.
$11^h\,26^m6$. The star was easily seen west of Jupiter II. It looked as though the occultation had not been central but that instead the star had passed north of the center of the satellite.
$11^h\,29^m3$. The star was 3″ or 4″ west-northwest of Jupiter II.
$11^h\,34^m$. A line through the centers of the discs of Jupiter II and the star missed the limb of Jupiter by *about* 5″, passing to the south of it.
$11^h\,43^m$, $11^h\,59^m$. With 141x and slightly better seeing than earlier, the line just mentioned now appeared to be almost tangent to the southwestern limb of Jupiter.
It is estimated that mid-occultation came at $11^h\,20^m2$, a value perhaps accurate to within one minute.

It would be of interest to investigate by a mathematical calculation the theoretical conditions of visibility of the occultation. The writer suspects that some of his estimated separations are too small; he doubts, for example, that his telescope would have the resolving power to show a ninth magnitude star only 1″ away from a sixth magnitude satellite. It is *possible*, in fact, that the star was not actually occulted at all but merely approached close enough to the satellite to be invisible for a while. The writer's opinion that an occultation did occur rests upon the observed positions of the star relative to the satellite both before and after the period of invisibility.

Jupiter being near quadrature on April 12, this phenomenon could have been seen over only a small range of terrestrial longitudes; and no other observations are known to the writer. It would be very interesting to learn of any others that may have been made.

Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico, U.S.A., May 3, 1949.

Climate in the Upper Midwestern United States, and its Relation to Sunspots

By FRANKLIN J. RYDER

For centuries past, we humans have abided by the oft-quoted remark that "everyone talks about the weather but no one does anything about it." That climate and weather play controlling roles in agriculture, industry, transportation, public works, and pleasure is obvious; but only

lately, refrigeration, air-conditioning, and most important, the long range considerations of the trend of climate are freeing man from weather's caprices. It is the purpose of this paper to discuss the influence of climate in North-Central United States, the possible relationship of climate to sunspots, and the practical applications of such a relation.

First, may I define my terms? Climate implies an over-all summation of the day to day variations in meteorological conditions, a long time integration of the weather. The year is taken as the unit of time in this study.

For those interested in the history of Minnesota and adjacent states, several excellent works are listed in the bibliography. (1, 2, 17.)*

The method of analysis used was suggested by J. B. Kincer. (3, 4). For the entire period of record, the mean annual temperatures and the total annual precipitation recorded at Minneapolis, and the average values for Minnesota together with Wolf Sunspot Numbers were subjected to a ten-year moving average, where the entry under each date represents the sum, or average for the base period up to and including the respective dates of entry. For example, the entry for 1900 represents the sum of the mean values for the 10 years 1891 to 1900, inclusive. These ten-year moving averages seem to be fair indicators of climate variations.

There are two interesting points which such an analysis indicates. First, the temperature and precipitation curves for areas as large as the state of Minnesota coincide almost exactly with those for an individual Weather Bureau station such as Minneapolis. Secondly, the trend of temperature is almost the inverse of the precipitation trend. As the temperature trend declines, the trend of precipitation rises. Peaks of precipitation correspond to sags of temperature.

Twenty-five miles west of Minneapolis is Lake Minnetonka drained by Minnehaha Creek made famous in Longfellow's poem, "Hiawatha." The levels of this lake correspond amazingly to the ten-year moving average of precipitation and vary inversely to that of temperature. This is to be expected.

The general trend of temperature indicates that the decade ending in 1837 up to 1869 there was a definite temperature recession and thereafter was warm, rising irregularly to a high in 1939. Minor peaks in this ten-year average occurred in 1872, 1886, and 1904. Since 1939 temperature trend has declined. Precipitation increases irregularly from 1849 to an all time high in 1874, sagging for the next two decades and then rising to a secondary peak in 1909. Ten-year average of precipitation sagged again to an all time low in 1936. Precipitation is now on the increase.

Many eminent authorities hold that a large number of sunspots, and hence increased solar radiation, appear to cause a greater degree of

*Numbers refer to items listed in the Bibliography.

evaporation from the earth's surface, and hence a higher vapor content of the earth's atmosphere, greater prevalence of clouds and rainfall. (7, 8.) This is apparent in that the ten-year moving average of the Wolf Sunspot Numbers approximates the moving average of temperature, and is the inverse of the precipitation.

It is hardly necessary to indicate the effects of climate. In Minnesota and Wisconsin particularly, the tourists make the most of the climate. Throughout the Midwestern United States, of course, the extensive development of agriculture is dependent wholly on climate.

No mention of climate in the Upper Midwest would be complete without referring to Dr. George F. Will's "Tree Ring Studies in North Dakota." (5). Dr. A. E. Douglas developed a method of reading weather data from tree rings. (6). Through his studies, Dr. Will has not only traced the "occupation of the area adjacent to the Missouri River by an Indian agricultural population since approximately 1400 A.D.," but has, in a manner similar to that of Dr. Douglas, specifically recorded, through tree ring analysis, precipitation in North Dakota for over 530 years. To quote Dr. Will, "It becomes perfectly clear that years of drought and moisture seem to run in series, sometimes separated by from one to several years of average rainfall. . . It appears impossible to work out any definite pattern as to the numbers of years in succeeding series. That number varies greatly from one year to a maximum of thirty-nine wet years and twenty dry years. At certain periods there are very short successions of one to three wet years followed by an equally small number of dry years."

Shortly after completion of the last Federal Census in 1940, the Weather Bureau announced that population follows precipitation. Said the Weather Bureau, "Only five states showed a decrease in inhabitants. And they were the ones hardest hit by the drought. These states (North Dakota, South Dakota, Nebraska, Arkansas, and Oklahoma) in the previous decade of above-normal precipitation were among those showing the greatest increase in crop acreage. . . In every one of the five states, there was below normal precipitation during at least 7 of the 10 years. Obviously the danger is over—optimism during the wet phases, with an unjustified extension of cultivation into the normally drier areas, certainly to be followed . . . by conditions unfavorable to crop growth."

In a recent history "Land of Dakotahs," (9) Mr. Bruce Nelson paints a poignant picture of immigrants to the Missouri River Valley bent on making the most of a fertile inland empire, falling victim to Indians, land speculators, but most of all to the fickle caprices of climate —at one season, rain and hail beating crops to the ground, and again, parching droughts during which no crop could grow.

Mr. George B. Gleason (10) points out another phase of variations in climate. Although pertinent to California, but applicable to mid-continental United States also, Mr. Gleason stated that "One charac-

teristic of . . . weather, quite significant from the water supply standpoint is that periods of several years averaging materially wetter than the long time average, alternate with periods about equally long which are correspondingly dry. Water-table elevations at a long-record well reflect this "cyclic" variation as well as the variation in supply and extractions during each year . . ."

Dr. C. C. Wylie, Professor of Astronomy, State University of Iowa, has shown a direct correlation between the yield of corn in Iowa to sunspots. By personal correspondence, Professor Wylie reports "a positive correlation of flow of water in midwestern rivers with the sunspot cycle, which is definitely higher than the precipitation curve for the same years. . . This was an evaporation effect since the runoff is only a fraction of the total rainfall. It seemed reasonable that the evaporation being higher in the warmer years would leave more water to go down the river in the cooler years. This conclusion was complicated, however, by the fact that in the New England states the runoff was higher at a different time in the sunspot cycle."

Another odd effect of climate has been reported by jewelers in St. Paul. Watch repair business increases every summer during the thunderstorm season. Jewelers seem to agree that main springs break most frequently after a thunderstorm. Cause of such troubles is the expansion and contraction of the highly tempered metal of which the main spring is made. The occurrence of thunderstorms appears to increase at times of sunspot minima.

Bordering between climate and weather is a phenomenon evident in mid-continental United States. Noticeable both in temperature and in precipitation are the "7, 14 and 28 day cycles." These cycles are apparent in that a given meteorological condition—cloudiness, rain, snow, sunshine, etc.—appears to repeat itself on the 7th, 14th, and 28th day after its initial occurrence. The penultimate explanation of this is that the particular meteorological condition travels north along the east coast of Asia, across Alaska, diagonally southeastward over Canada, over Minnesota, the Great Lakes and New England regions, over the North Atlantic, Europe, Asia, and thence again over its original course. It has been suggested that this peculiarity of weather has its ultimate cause in planetary motion. The late H. H. Clayton (11) has given some attention this matter.

A new innovation in man's attempt to control the effects of climate has been introduced. The Wisconsin State Conservation Department early in the spring of 1947 dropped lampblack on ice-covered lakes to melt the ice and allow air to reach the fish in the water below. Since fish drown when thick ice prevents oxygen from getting into the water, the lampblack is expected to absorb the sun's rays, and melt the ice. (16).

To conclude, may I leave only a single thought? Climate and sunspots are intimately related. Climate probably influences human affairs

more than any other environmental factor, for, without a favorable climate, men cannot exist. A case in point is the now desolate Sahara desert which once supported a highly cultured people. (12). There is an apparent dependency between the long range trend of climate and sunspots, the empirical determination of which would be an invaluable tool.

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1718 HENNEPIN AVE., MINNEAPOLIS, MINNESOTA.

The Planets in July and August, 1949

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. The season of greatest heat for most northern localities occurs near the middle of this period. However, the sun will already be moving southward during all the period and, at the end, will stand less than 9 degrees north of the equator. On July 2 the earth will be at aphelion, so that the sun will be at its greatest distance from the earth.

Moon. The phases of the moon will occur as follows:

First Quarter	July	3	2 A.M.
Full Moon		10	2 A.M.
Last Quarter		17	12 P.M.
New Moon		25	2 P.M.
First Quarter	August	1	7 A.M.
Full Moon		8	2 P.M.
Last Quarter		16	5 P.M.
New Moon		23	10 P.M.
First Quarter		30	1 P.M.

The moon will be nearest to the earth on July 2 and 28, and on August 25.

Evening and Morning Stars. Venus and Saturn will decorate the western evening twilight; Jupiter will appear in the east shortly later. Mars may be seen in the eastern morning sky.

Mercury. Having just passed a greatest elongation west, Mercury may be glimpsed in the eastern dawn during the first week of July.

Venus. Due to the unfavorable southward tendency of the ecliptic where Venus will be moving rapidly eastward, this brightest planet will make little progress in visibility during the period. It will always set within an hour and a half after the sun. Its very close conjunction with Saturn on July 30 will be of interest.

Mars. Although it will still be relatively faint, Mars will be somewhat favorably situated in the morning sky, where it will rise up to 3 hours ahead of the sun.

Jupiter. By reaching opposition and all-night visibility on July 20, Jupiter will become definitely the "planet of the month" for both July and August.

Saturn. Although fast fading in the evening twilight, this interesting planet may have its visibility extended by close association with the brighter Venus, which will pass less than a quarter degree to the south on July 30.

Uranus. While Uranus will be rather close to the sun for convenient observation in the morning sky, a close conjunction with Mars on July 27 will be of telescopic interest. The red planet, moving eastward faster than Uranus, will pass only a quarter of a degree north of it.

Neptune. Neptune will be moving very slowly southeastward at a position 3 degrees southeast of γ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.,
May 6, 1949.

Asteroid Notes

By HUGH S. RICE

VESTA and HEBE are good for observation during the first half of the summer, as shown by our notes in the last issue.

Besides these, the following four asteroids are observable at this time. LAMPETIA is in Aquila, at opposition July 18, and of magnitude 8.7. On July 21 it is in conjunction with the star Altair, the asteroid being about 2° 12′ north. On July 29, it passes by Gamma Aquilae in conjunction, the planet being only about 21′ north. AMPHITRITE is in southern Capricornus, at opposition July 31, and of magnitude 9.2. ARIADNE is in southern Aquarius, at opposition August 7,

and of magnitude 9.0. HARMONIA is in Capricornus at opposition August 11, and of magnitude 9.0.

ASTEROID EPHEMERIDES

For 0^h U.T. Equinox 1950

393 LAMPETIA

1949	α	δ
	h m	° ′
June 29	19 59.4	+ 9 1
July 7	19 56.0	+10 8
15	19 51.6	+10 48
23	19 46.9	+10 58
31	19 42.3	+10 37
Aug. 8	19 38.9	+ 9 50

29 AMPHITRITE

1949	α	δ
	h m	° ′
July 15	20 57.2	—25 25
23	20 49.9	—25 48
31	20 41.9	—26 8
Aug. 8	20 33.8	—26 21
16	20 26.2	—26 25
24	20 19.8	—26 20

43 ARIADNE

1949	α	δ
	h m	° ′
July 15	21 25.5	—10 14
23	21 20.6	—10 12
31	21 13.7	—10 21
Aug. 8	21 6.0	—10 37
16	20 58.5	—10 58
24	20 52.0	—11 22

40 HARMONIA

1949	α	δ
	h m	° ′
July 23	21 40.1	—18 49
31	21 33.7	—19 44
Aug. 8	21 26.3	—20 38
16	21 18.5	—21 28
24	21 11.0	—22 10
Sept. 1	21 4.6	—22 41

Hayden Planetarium, American Museum of Natural History, New York, May 22, 1949.

Occultation Predictions for July and August, 1949

(Taken from the *American Ephemeris*)

Date 1949	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
July 1	*l* Leon	5.3	2 6.8	—0.8	—0.8	62	2 35.6	+0.5	—2.6	357
6	50 B.Scor	6.4	23 43.1	—2.0	+1.4	74	0 38.5	—0.6	—1.0	337
13	29 Aqar	6.5	7 36.4	—0.7	+1.6	18	8 42.1	—2.2	—0.7	271
20	δ Arie	4.5	6 21.4	+0.3	+1.9	46	7 18.7	—0.4	+1.6	259
23	415 B.Taur	6.1	8 16.6	+0.3	+1.4	74	9 11.8	—0.1	+1.4	265
Aug. 7	*A* Sgtr	5.0	6 48.9	+0.2	+1.0	18	7 33.9	—1.5	—2.3	296
19	107 B.Auri	6.5	7 33.6	+0.3	+2.3	41	8 26.5	—1.1	+0.8	289
26	VENUS	—3.4	.. ..	..	..	..	14 4.3	—0.4	+1.0	282
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′										
July 1	*l* Leon	5.3	1 52.8	—1.1	—1.4	93	2 46.0	0.0	—2.2	335
7	85 B.Scor	6.2	5 46.0	—1.4	0.0	50	6 33.3	—1.7	—2.6	332
Aug. 3	31 B.Scor	5.4	2 30.7	—2.0	—0.5	84	3 44.3	—1.6	—1.7	311
16	45 Arie	5.9	6 42.0	—2.0	—0.2	129	7 4.2	+1.7	+4.2	170
19	107 B.Auri	6.5	7 41.5	+1.5	+3.3	9	8 4.8	—1.4	—0.7	321
30	α Scor	1.2	21 27.6	—3.2	+3.1	50	22 0.3	+0.7	—2.3	354
OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +31° 0′										
July 1	*l* Leon	5.3	1 59.4	—0.9	—1.7	119	3 3.0	—0.3	—1.8	312
7	85 B.Scor	6.2	5 33.7	—2.2	—0.1	70	6 41.7	—1.9	—2.1	316
8	95 G.Ophi	6.1	3 23.7	—3.9	+2.9	44	4 4.1	—0.7	—3.1	348
13	29 Aqar	6.5	6 48.7	..	..	354	7 23.6	—4.2	—1.7	307
Aug. 3	31 B.Scor	5.4	2 20.2	—2.4	—0.7	104	3 45.8	—2.0	—1.4	296
5	210 B.Scor	6.0	5 9.9	—1.2	+1.8	29	5 57.7	—3.0	—2.9	321
30	α Scor	1.2	20 59.3	—1.2	+0.8	96	22 8.0	—0.9	—0.5	315

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

July 7	85	B.Scor	6.2	4	38.9	−2.5	+0.5	80	5	50.6	−1.7	−1.4	323
8	95	G.Ophi	6.1	2	38.5	−1.4	+1.4	79	3	40.2	−0.7	−0.4	319
8	43	Ophi	5.4	9	2.1	−1.0	+0.1	50	9	59.3	−1.6	−2.1	308
14	74	Aqar	5.9	8	55.1	−2.0	+1.2	86	10	7.7	−1.1	+2.2	202
17	73	Pisc	6.2	11	19.6	−3.7	−0.1	110	11	58.5	+1.2	+4.5	167
20	63	Arie	5.2	11	45.3	−1.0	+1.5	79	12	53.5	−0.6	+2.5	217
Aug. 1	621	B.Virg	6.4	3	24.1	−1.3	−1.9	145	4	32.6	−1.4	−1.3	276
3	31	B.Scor	5.4	1	35.1	−1.3	−0.3	127	2	55.1	−2.1	−0.3	287
3	40	B.Scor	5.4	4	27.7	−2.2	−0.6	90	5	46.4	−1.7	−1.6	303
30	42	Libr	5.1	2	39.2	−2.1	−0.6	87	3	53.3	−1.6	−1.8	311
30	α	Scor	1.2	..	..	..	..	..	21	51.1	−0.6	+0.6	288
31	134	B.Scor	6.4	5	9.4	−1.5	−1.3	103	6	20.5	−0.7	−1.0	265

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

Reduced Meteoritic Iron Oxide

JOHN DAVIS BUDDHUE
99 South Raymond Avenue, Pasadena 1, California

ABSTRACT

Weighed pieces of Canyon Diablo, Arizona, oxide were reduced to metal by heating in hydrogen. In two cases, the oxide was analyzed before reduction, and the resulting metal was analyzed after reduction. From the data obtained, it is possible to calculate the oxygen content of the original oxide by three different methods. The results are in fair agreement, and indicate an oxygen content of about 29%.

The study of meteoritic iron oxide is a rather neglected subject. As far as I am aware, the only previous case in which an oxidized meteorite was reduced back to metal was in an experiment by Meunier.[1] In this case, a piece of metal from the Charcas, San Luis Potosí, Mexico, meteorite (cl. = Om; C.N. = 1010,231) was suspended in superheated steam for 5 hours. The resulting oxide did not show any Widmanstätten figures. Later the oxide was reduced back to metal by heating in hydrogen; this metal also did not show any Widmanstätten figures. My first experiments consisted in heating 4 weighed specimens of the

oxide from the vicinity of the Canyon Diablo, Arizona, Crater (C.N. = 1110,350A) in hydrogen. After reduction, these were weighed again, and the weight loss was taken as a rough indication of the oxygen content. The results were as follows:

TABLE 1

Description of Specimen	Wt. Loss
Lamellar oxide	33.2%
Somewhat lamellar	34.6
Compact, yellowish	25.6
Breadcrust surface	28.5

The loss in weight included, of course, not only oxygen, but also any moisture, carbon dioxide, and organic matter that might have been present. The resulting bits of metal were light gray in color, and retained the shape of the oxide very well, altho the reduction took place at a temperature only slightly below that of the melting point of iron; they were also very porous. The pores had the form of numerous curving cracks, some of them visible to the naked eye, but most of them very narrow, and some perhaps microscopic. Several pieces of the reduced oxide were coated with a solution of nitrocellulose to keep water out of the cracks, and the specific gravity was then determined by the pycnometer method. The result was 5.00 at 25° C. Taking the specific gravity of pure iron as 7.85, I found that the porosity of the reduced oxide was 36.3%.

For later experiments, a fairly large piece of lamellar oxide from the Canyon Diablo Crater was carefully broken up, and two rather large, flat, slabs consisting of single lamellae were selected. One, which will be called "A," came from the surface of the original lump and had "desert polish" on one side. The other, which will be called "B," came from the interior of the original lump. Both appeared to be free from deposits of secondary oxide and of calcium carbonate, which are so common on Canyon Diablo specimens. Parts of each slab were saved for analysis, and the remainder was weighed and reduced in hydrogen at a somewhat lower temperature than before. After reduction and reweighing, a portion of the metal was analyzed. The analyses were made by Mr. F. G. Hawley. The composition of the original samples of oxide was as follows:

TABLE 2

	A	B
Fe_2O_3	81.39%	82.85%
FeO	4.24	4.37
NiO	7.02	6.54
H_2O	4.50	3.44
Insol.	0.68	0.60
Totals	97.83%	97.80%

The totals are less than 100% because of undetermined minor constituents. The close agreement between the two analyses is somewhat surprising when compared with the wide divergences between other analyses of this oxide. It seems likely that if some of the other analyses had been made on parts of the same mass, the agreement might have been better.

The composition of the metal can be computed from these analyses. This computation has been made, and the results are given in Table 3, in comparison with the composition as determined by Mr. Hawley.

TABLE 3

	Computed		Determined	
	A	B	A	B
Fe	90.75%	91.50%	89.20%	89.90%
Ni	8.30	7.65	8.48	8.64
Insol.	1.02	0.89	0.92	0.89
	100.07%	100.04%	98.60%	99.43%

The best way to determine the oxygen content of the oxide would be to collect the water formed during the reduction and weigh it. After making a correction for the amount of water originally present in the sample, the oxygen content could be easily calculated. Unfortunately, this method was not practicable, because the reductions were made for me by a friend whose work requires the use of a furnace which has a hydrogen atmosphere, but which makes no provision for collecting the water formed. There are, however, three other ways in which the oxygen content can be ascertained: (1) The loss in weight during reduction, with a correction for the amount of the original moisture, will give the weight of oxygen plus carbon dioxide plus organic matter. The last-named two materials were in this case probably very small. (2) From the analyses in Table 2, the amount of oxygen in the three oxides, after eliminating moisture and insoluble matter, can be calculated. (3) After eliminating moisture and insoluble matter, the equivalent quantities of the metals can be calculated. Oxygen is then obtained by difference. The oxygen content, according to these three methods, is given in Table 4.

TABLE 4

Method	A	B
(1)	27.05%	28.55%
(2)	29.59	29.63
(3)	28.94	29.04
Mean	28.52%	29.07%

My thanks are due to Mr. Howard Martens for reducing these samples of oxide.

References

[1] S. Meunier, *Compt. Rend.*, **77**, 645, 1873.

Dean M. Gillespie, 1884-1949

H. H. Nininger
American Meteorite Museum, Box 1171, Winslow, Arizona

February 2, 1949, marked the passing of one of the Charter Members and one of the first two Patrons of the Meteoritical Society. It was my pleasure and privilege to know and to be associated with Mr. Dean M. Gillespie of Denver, Colorado, for many years, during which he did much for the development of the young science of meteoritics. Mr. Gillespie was, from first to last, a business man, but he was one of those rare persons whose mind, even tho carrying a multitude of business responsibilities, would inevitably "spark" at the mention of any new fact or idea related to meteoritics. He was among the first to recognize the importance of meteoritical research along the lines which meteoritics is now moving, and he often spoke wistfully of his personal desire to help establish the research institute, plans for which absorbed so much of my time in the 1930's; and when Dr. Frederick C. Leonard finally persuaded me to help him organize the Society for Research on Meteorites (now the Meteoritical

Society) in 1933, Mr. Gillespie was the very first layman to express a wish to join it. Financial reverses in the course of that period prevented him from doing what I always felt he would have liked to do for the Society. The only substantial gift he ever made to the organization consisted in the purchase of the entire remaining stock of O. C. Farrington's book on *Meteorites* (1915) and the presentation of 90 per cent of that stock to the Society for re-sale.

He was intensely interested also in the program that our laboratory was carrying on in those days, of combining meteoritical education with a field search for meteorites; and, altho we on various occasions received support of one kind or another from other institutions and individuals, it was upon Mr. Gillespie more than upon any one other source that we depended for the financial backing necessary. His help was not in the form of gifts, but easy loans, and the financing of field expeditions for a share in the finds recovered. The period from 1930 to 1942 was a most critical one for us, one in which we could never see more than a few months ahead what was to be the source of our living expenses and funds for research; yet we always managed to meet our obligations, which involved several thousand dollars a year above our personal needs. This accomplishment would not have been possible if Mr. Gillespie had not been there to call upon for a few hundred dollars when such a loan was needed. With all of his interest and his willingness to help out in a pinch, Mr. Gillespie always stood firmly on business principles. He demanded and received his full share when a venture proved fruitful. One the other hand, when a venture failed to yield fruit, he was a good loser. Not infrequently, when a project seemed to offer slender promise of returns, I would guarantee its cost by supplying meteorites already in my possession and thus secure the help needed. The Gillespie collection grew rapidly thru the years by all these means, while at the same time our own collection continued to increase. At the time of his death, the Gillespie collection was one of the few really large private collections extant.

One of his chief interests was the Barringer (Canyon Diablo, Arizona) Meteorite Crater and the nickel-iron meteorites associated with it. My instructions from him were never to pass up an opportunity to purchase one of those irons without letting him know. His Canyon Diablo irons make up a considerable portion of the Crater exhibit now to be seen in the American Meteorite Museum. One of his great ambitions, as often expressed to me, was that he might some day participate in a search for meteorites around the Crater. This was always a subject for discussion in each of our several last meetings; but, like many men of affairs, he, I fear, let business cheat him out of one of the greatest pleasures that life could have given him. Death came apparently quite unexpected, else he might have proved to be a great boon to research in this field.

Regardless of what he might have done, it must be recorded to his credit that his help rendered possible the carrying out of the program that resulted in the discovery of more meteorites in the 1930's than were found by all other forces in the world combined; and further that, in spite of the fact that he was not scientifically trained, he saw the scientific implications of our meteorite survey more quickly and more clearly than did the majority of the scientists of those years.

In the death of Dean M. Gillespie, the young science of meteoritics has sustained a heavy loss, and some of us have lost a great and good friend.

Notice of the 12th Meeting of the Society

The 12th Meeting of the Meteoritical Society will be held on Tuesday, September 6, and Wednesday, September 7, 1949—scientific sessions opening at 9 A.M. and 2 P.M.—at the University of Southern California, Los Angeles, California.

Members of the Society are hereby requested to send the undersigned, at their earliest convenience, the titles and abstracts (the latter in form for publication in *C.M.S.*) of any papers that they may wish to present, or to have presented, at the meeting, of which all the scientific sessions will be open to the public and at which guests, as well as members, will be welcome.

JOHN A. RUSSELL, *Chairman, Program Committee for the 12th Meeting*

Department of Astronomy, University of Southern California, Los Angeles 7, California, 1949 May 1

Dr. Harrison Brown at the U.C.L.A.

From April 11 to May 19, 1949, Dr. Harrison Brown of the Institute for Nuclear Studies and the Department of Chemistry of the University of Chicago served as a visiting research professor in the Institute of Geophysics of the University of California. In the course of that time he delivered three public lectures at the University of California, Los Angeles, the headquarters of the Institute of Geophysics, as follows:

April 19: "The Neutron Pile as a Tool in the Quantitative Determination of Trace Constituents in Meteoritic Matter";

May 5: "The Experimental Determination of Cosmic Nuclear Abundances";

May 6: "The Composition of Meteoritic Matter and its Bearing upon the Origin of the Solar System."

While in California, Dr. Brown lectured on his work in meteoritics also at the University of California, Berkeley, the California Institute of Technology, Pasadena, and the Scripps Institution of Oceanography of the University of California, La Jolla. On his way West he made short visits at the Institute of Meteoritics of the University of New Mexico, Albuquerque, the Canyon Diablo, Arizona, Meteorite Crater, and the American Meteorite Museum, near Winslow, Arizona. He was accompanied on the trip by his assistant, Miss Rudd Harris.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: OSCAR E. MONNIG, 1010 Morningside Drive, Fort Worth 3, Texas

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

The Eclipsing Variable μ^1 Scorpii: In a recent number of *Monthly Notices*, D. W. N. Stibbs of the Commonwealth Observatory, Canberra, Australia, reports on his photometric study of the eclipsing variable μ^1 Scorpii. The variable was the third spectroscopic binary to be discovered—in 1896 by Bailey at Harvard—

and its light curve showed a very distorted shape before rectification. Stibbs made a series of measures in effective wave length 3970A, securing more than 300 observations over an interval of 100 days, with the result that a very complete and well-defined light curve was obtained.

The star had been previously studied by Miss Maury, Rudnick and Elvey, and van Gent, who derived times of principal minima as follows:

Maury	JD 2415591.6830
Rudnick and Elvey	2428281.250
van Gent	2428414.2978
Stibbs	2432001.0451

from which mean periods of $1^d.44626831$ and $1^d.44626907$ were derived, indicating no significant difference between them.

It is of interest to show a comparison of the data derived from the works of Stibbs, Rudnick and Elvey, and van Gent as shown in the following table.

	Stibbs	Rudnick and Elvey	van Gent
	m	m	m
Depth Primary Min.	0.276	0.29	0.30
Depth Secondary Min.	0.164	0.18	0.19
Ratio Mean Surface Brightness	1.916	1.640	2.32
Light, smaller star	0.606	0.568	0.606
Light, larger star	0.394	0.432	0.394
Ratio of Radii	0.90	0.90	0.81
Maximum Obscuration	0.183	0.237	0.155
Inclination Orbit	60°0	62°0	61°1
Semi-axis major smaller star	0.365	0.360	0.326
Semi-axis major larger star	0.405	0.400	0.402
Semi-axis minor smaller star	0.313	0.318	0.266
Semi-axis minor larger star	0.347	0.354	0.328
Radius relative orbit	1.068×10^7 km	1.048×10^7 km	1.056×10^7 km
Mass, smaller star	14.01⊙	13.22⊙	13.56⊙
Mass, larger star	9.24⊙	8.72⊙	8.94⊙

The apparent magnitude of μ^1 at maximum is 3^m106, assuming that of μ^2 to be 3^m680. Therefore the apparent magnitudes of the two components of μ^1 are 3^m650 and 4^m117, respectively. The absolute magnitues of the components are -2^m7 and 2^m3, using Blaauw's value of the parallax as $0''.0053 \pm 0''.0004$. The components are of spectral type B3p and B6.

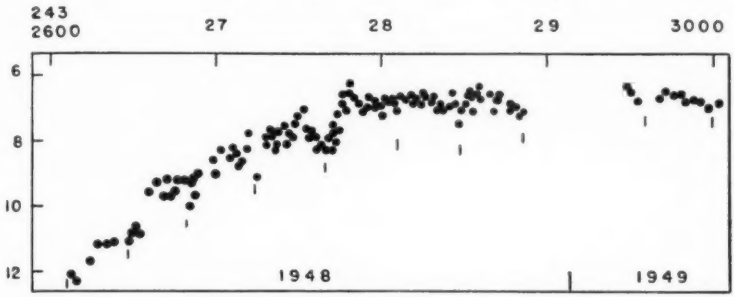
The R Coronae Borealis Variables

R Coronae Borealis itself has remained at or near 14th magnitude since the middle of February, with no indication at the present date (May 10) of rising to maximum. The decrease in light from maximum brightness at 6.0 began about November 20, 1948, and, with the exception of two interruptions, the star fell rather rapidly to minimum. The previous decrease to minimum occurred during November and December, 1946, and the variable was back at normal maximum again six months later. The star faded away on that occasion only to magnitude 11.5.

SU Tauri has remained at maximum (magnitude 9.5) for the past three years, with only slight fluctuations in light.

S Apodis, which began its most recent descent to minimum in the fall of 1946, is still faint, hovering between magnitudes 12.8 and 14.5. For a time, early in 1947, the variable was recorded as fainter than magnitude 15. A year ago the star passed through a temporary increase in light to magnitude 12.8, after which it dropped to magnitude 14, where it has since remained (to April 1st).

RY Sagittarii, the fourth of the R Coronae Borealis stars on the AAVSO observing list, has been at maximum since May, 1948, around magnitude 6.8. The most interesting feature concerning this variable is that the 40 day cycle in fluctuations, noted by Dr. Luigi Jacchia some years ago, is very well indicated in the observed light curve covering the past fourteen months, being prominent not only at maximum light but also on the increase from minimum to maximum.



LIGHT CURVE OF RY SAGITTARII, 1910*33*, FROM FEBRUARY, 1948, TO MARCH, 1949. (Note 40-day cycle)

(See the figure.) Points are daily means. Probable dates of minimum are indicated by short lines.

Observations received during April, 1949: During the month of April, 3,811 estimates were received from 61 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Ahnert, P.	41	286	Halbach	40	56
Albrecht	12	16	Hartmann	122	133
Ancarani	20	62	Herring	8	9
Ashbrook	1	14	Hiett	10	12
Bajocchi	9	26	Kelly	10	10
Ball	9	9	Kirchhoff	31	58
Bappu	23	38	de Kock	108	369
Bicknell	5	11	Lacchini	47	78
Bogard	58	140	Lankford	6	31
Buckstaff	6	7	Lee	38	150
Bufkin	3	4	Leinbach	7	7
Cain	27	31	Lowder	6	7
Caraioryis	7	7	Luft	5	21
Chandra	3	4	Miller	20	20
Charles	7	10	Naef	5	31
Cilley	23	50	Oravec	44	129
Cragg	32	32	Parker	32	32
Daley	12	19	Parks	16	16
Darling	4	10	Pearcy	79	109
Davis	6	22	Peltier	101	166
Dillon	3	6	Penhallow	22	30
Drakakis	11	156	Pierson	65	66
Escalante	29	30	Renner	112	112
Estremadoyro	9	16	Rosebrugh	14	88
Fernald	295	677	Schoenke	2	2
Focas	21	32	Taboada	81	83
Gingerich	9	12	Tarbell	3	10
Greenley	55	135	Tifft	5	5

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Venter	10	33	Yamada	13	33
Waters	2	2	—		—
Webb	16	16	61	totals	3811
Wells	5	5			

May 10, 1949.

Comet Notes

By G. VAN BIESBROECK

No new comets have been discovered so far in 1949. COMET 1948 *d* (PAJDUSAKOVA-MRKOS) and COMET 1948 *l*, which was conspicuous in the southern hemisphere last November, are now too close to the sun to be followed further.

This leaves only two very faint comets in reach of northern stations namely the two periodic ones SCHWASSMANN-WACHMANN I and II. They remained extremely faint during the month of April. Southern observers should still be able to follow COMET 1948 *h* (WIRTANEN) which was due at perihelion in the beginning of May and expected to reach 12th magnitude in the latter part of this month. It is however located very far south.

All efforts to find the expected PERIODIC COMET 1927 VI (GALE) have failed. It was looked for in vain at the Lick, Yerkes, and Link Observatories and also in South Africa at Johannesburg where the conditions of visibility were much more favorable. According to a letter from Dr. Merton, the English computers feel confident about their prediction. The comet has evidently undergone an unforeseen loss in brightness during the 11 years since the 1938 return, when it was found as a 10th magnitude object.

Two other faint PERIODIC COMETS 1916 II (NEUJMIN 2) and 1939 IV (VÄISÄLÄ 1) have not been found at their return this year on account of unfavorable location or extreme faintness. The latter one will however become somewhat brighter toward the end of this year.

Williams Bay, Wis., May 11, 1949.

General Notes

The attention of the readers of this journal is called to the fact that the next issue, that for August, is not due until August 1. In fact subscribers should not be disappointed if the August copy does not arrive until some time after August 1. The editor is planning an astronomical pilgrimage to the large observatories on the Pacific coast during the summer months, and the August number will be delayed until his return. However, no issue will be omitted, and the usual publication schedule will be resumed in October. EDITOR.

Dr. J. H. Moore, a member of the Lick Observatory staff for many years and later the director of the Lick Observatory, died on March 15, 1949, at the age of seventy.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on May 13, 1949, at the Randal Morgan Physics Laboratory, University of Pennsylvania. The speaker, Dr. Edgar W. Woolard, U. S. Naval Observatory, spoke on the topic, "The Impress of Past Ages on Modern Astronomy."

Publications of the University Observatory at Göttingen.—A packet of these publications, numbered from 71 to 90, inclusive, has recently been received. They are for the most part 16-mo pamphlets of an average of eight or ten pages each. They relate to a wide variety of topics and are by a number of different authors. In time they range from 1941 to 1948. In the series No. 75 is dated 1943 and No. 76 is dated 1947. Some later numbers bear dates of the intervening years. This indicates that the research was done during the war years and published after the war. It is gratifying to note this renewed activity at this well-known astronomical institution.

The Lunar Crater Russell W. Porter

Since the publication of the biographical sketch of Dr. Russell W. Porter in the preceding issue, we have learned, through an article in *Scientific American* for May, of an additional recognition of his contributions to astronomy. This honor is in the form of naming a crater on the moon for him. On the edge of Clavius, a mountain-walled plain in about 60° south latitude, there are two small craters known formerly as Clavius A and Clavius B. Later Clavius A was given the name Rutherford, and now Clavius B is to be named Russell W. Porter. It is very fitting that this should be done. Other Americans whose names are associated with features on the moon are Bruce, Burnham, Mitchell, Hall, Newcomb, Ritchey, Rutherford, Lick, Yerkes. To this list is added now the name of Porter.

Additional Note on the "Green Flash"

Prompted by mention of the "Green Flash" in previous issues of this journal, Professor W. Norlind writes as follows:

"The phenomenon is however not so seldom observed as the recorders, perhaps, are inclined to assume. Indeed I have myself seen it several times in the years 1922-49 at my observatory in Barsebäck, Southern Sweden (lat. +55° 45′, long. $0^h\,51^m$ E., Alt. :2^m), situated some 300 meters from the shore of the Sound. Perhaps it may therefore interest you and the readers of your journal to get a complete record of my observations, which I have looked up in my notebooks."

Then follows a list of dates in the interval mentioned on which the "Green Flash" was clearly seen, and also the dates when it was looked for but not observed. The former number 26, the latter 13.

A New Series of Astronomical Papers

Readers of this journal in recent years will recall the series of papers designated as "Astronomical Summaries." They were intended to set forth the development in certain areas of astronomical research during the preceding half-century, the period representing the age of this journal when the series was begun. The series of "Astronomical Summaries" as planned is now nearly completed.

Another series is now in progress. This will bring to our readers a number of papers bearing on the historical aspects of certain phases of astronomy. They

will be referred to as "Papers on Historical Astronomy." One such paper has already appeared. It was prepared by Dr. Otto Struve and it appeared in three parts in May, June, and October, 1947, under the titles, "The Story of an Observatory," and "Yerkes Observatory, 1897-1947." The second paper in the series appears in this issue, "The Quest for Stellar Parallax," by Dr. Dorrit Hoffleit. Other papers will follow in succeeding issues. EDITOR.

Provisional Relative Sunspot Numbers*

1	149	11	104	21	162
2	158	12	128	22	155
3	155	13	138	23	177
4	178	14	151	24	185
5	176	15	164	25	177
6	147	16	138	26	140
7	149	17	155	27	110
8	151	18	164	28	122
9	144	19	168	29	116
10	139	20	165	30	81

Monthly Mean 148.9

*From the Zürich Observatory, furnished by Mr. Neal J. Hines.

The 200-Inch Telescope

The Mt. Wilson and Palomar Observatory astronomers are engaged in the final stages of a 20-year telescope building project. This involves removing the 200-inch mirror from the Hale Telescope at the Palomar Observatory and polishing a portion of its surface a tiny bit more.

The announcement that the big mirror was to undergo additional polishing was first made last December by Dr. Ira S. Bowen, director of the combined observatories. Simultaneously with the release of some of the test pictures taken by the giant instrument last February and March Dr. Bowen said that the final "scrubbing" project would probably get under way in May.

Pictures released for general publication were taken by Dr. Edwin P. Hubble to record progress of the telescope adjustment program. The first pictures taken were so satisfactory that the big telescope was given a full scale run and pushed to its limit as it then stood. The results were pictures of extra-galactic nebulae estimated to be of the order of a billion light years (light travels at 186,000 miles per second) away from the earth. This is twice as far as any other telescope has ever been able to penetrate space. The 100-inch reflector at Mt. Wilson has gone out to approximately half a billion light years.

"Unfortunately, the most exciting pictures astronomically (the ones where the most distant objects have been photographed) become the least spectacular when you try to reproduce them on the printed page," Dr. Hubble said. The first such pictures taken with the Hale Telescope was of an area in the constellation of Coma Berenices.

To detect extra-galactic nebulae (huge galaxies like our own Milky Way) a billion light years distant required the use of a magnifying glass even when looking at the negative, Hubble explained. When prints are attempted on such pictures the problem of making them show for reproduction purposes becomes extremely difficult, he added.

"On none of the nights on which the pictures were taken were seeing conditions better than average," Dr. Hubble said. Practically all of them were taken

in February and March when weather in Southern California was far from ideal, and seeing was average or well below that. When Dr. Hubble obtained his first pictures, approximately 72 inches of snow covered the top of Palomar Mountain and astronomers were going about on snow shoes and skiis.

Electrically heated suits, Air Force war surplus property purchased by practically all the Mt. Wilson and Palomar staff last fall, stood the men of Palomar in good stead this winter when temperatures dropped well below the freezing point on the mountain.

The pictures already obtained show that at the present time the Hale Telescope is a far more powerful instrument than any other telescope. It already has reached out into space nearly as far as had been hoped, but astronomers will not be content until the telescope is capable of taking advantage of the finest possible "seeing" conditions. Consequently when a slightly turned up edge was revealed by a series of intricate tests of the entire surface of the big reflector, there was no hesitation in deciding that the edge must be polished down.

A band about 18 inches wide around the outer edge of the mirror will require repolishing. Even at the highest point only about 20 millionths of an inch of glass will be removed and over much of the band an even smaller amount will be taken off.

This work will be done at the observatory and it will not be necessary to transport the big mirror back to Pasadena, Dr. Bowen said. The mirror will be removed from the base of the telescope tube and the necessary polishing equipment rigged on the spot to do the job.

It is expected that as much as six months may be required to complete the polishing, after which the mirror will be put back in the telescope and again put through a long series of tests. It is anticipated that the big telescope will be ready for the beginning of a definite program of research late next fall, Dr. Bowen said. (*A news release from the California Institute of Technology.*)

Book Reviews

Kepler, by Max Casper. (W. Kohlhammer Publishing Co., Stuttgart, Germany. 18 Marks.)

A volume bearing the above title has recently been received from the publishers. It consists of 480 pages, including contents, bibliography, and index. One, who is not thoroughly familiar with the German language and therefore incapable of recognizing the fine shades of meaning possible in that language, cannot do justice to so important a volume as this. However, even a casual examination of it creates the impression that the writer spared no pains in the preparation of the book. As evidence of this, the name list at the end of the book contains more than 500 names of persons whose connection with the work of Kepler is referred to. The personal as well as the scientific phases of this rather well-known and picturesque character in early science are treated in great detail. The life of this man, perhaps more than in the case of the average man of his time, was beset with trials and tribulations. The science of his day was, in some respects, greatly at variance with the science of today, and in other respects, his science was definitely foundational.

The book is divided into six main parts as follows: I. Kepler's childhood and youth; II. Kepler as provincial mathematician and student in Graz; III. As royal

mathematician in Prague; IV. As mathematician in Linz; V. The closing years at Ulm and Sagan; VI. Summary and appreciation.

Any survey of the development of the science of astronomy will contain very prominently the name of Kepler. From this consideration it is safe to conclude that, for all those persons for whom the German language is not a barrier, the volume before us will be found of great value in establishing contact with the classical and basic fundamentals of this science. C.H.G.

Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who have sent them.

Contributions from the Mount Wilson Observatory:

No. 739. "A Photoelectric Guider for Astronomical Telescopes," by Horace W. Babcock.

No. 740. "Sunspot Groups of Irregular Magnetic Polarity," by Robert S. Richardson.

No. 741. "Radial Velocities of 204 Stars in the Region of the Hyades," by Ralph E. Wilson.

No. 742. "The Structure of the Atmosphere of the K-Type Component of Zeta Aurigae," by O. C. Wilson.

Nos. 743 and 744. "Wave Lengths of Atomic Absorption Lines in the Spectra of Long-period Variable Stars."
"The Spectrum of Z Andromedae in 1946 and 1947," by Paul W. Merrill.

No. 745. "The Ultraviolet Solar Spectrum, λλ 2935-3060," by Harold D. Babcock, Charlotte E. Moore, and Mary F. Coffeen.

No. 746. "Relative gf = Values for Lines of *Ni* I," by Robert B. King.

No. 747. "Spectroscopic Observations of 90 Stars," by Alfred H. Joy and S. A. Mitchell.

No. 748. "The Magnetic Field of Gamma Equulei," by Horace W. Babcock.

No. 749. "The Nuclear and Nebular Spectra of the Planetary Nebula NGC 2392," by O. C. Wilson.

No. 750. "Fine Structure of the Red System of Atmospheric Oxygen Bands," by Harold D. Babcock and Luise Herzberg.

No. 751. "The Balmer Series in the Spectrum of HD 45910," by Paul W. Merrill.

No. 752. "Relative Transition Probabilities of the Swan Bands of Carbon," by Robert B. King.

No. 753. "Six-color Photometry of Stars. VI. The Colors of Extragalactic Nebulae," by Joel Stebbins and A. E. Whitford.

Contributions from the Lick Observatory, Series II:

No. 21. "A Theoretical Discussion of the Ultimate Limits of Astronomical Photoelectric Photometers," by Harold L. Johnson.

No. 22. "Spectrophotometry of the Wolf-Rayet Star HD 45166," by F. J. Neubauer and Lawrence H. Aller.

No. 23. "Idealized Models and Rectified Light-curves for Eclipsing Variables," by Henry Norris Russell.

Contributions from the McDonald Observatory:

No. 133. "Radial Velocities and Absolute Magnitudes of Be Stars," by Burke Smith.

No. 134. "The M-Type Supergiant Members of the Double Cluster of Perseus," by W. P. Bidelman.
No. 135. "The Variation in Radial Velocity and Spectral Type of the Ultra-Short-Period Variable, DY Pegasi," by W. P. Bidelman.
No. 136. "The Absorption Continuum in the Violet Region of the Spectra of Carbon Stars," by G. Shajn and O. Struve.
No. 137. "Spectrographic Observations of Eight Eclipsing Binaries," by Otto Struve.
No. 138. "The Spectrum of the Eclipsing Binary UX Monocerotis," by Otto Struve
No. 139. "The Infrared Stellar Spectrometer," by G. P. Kuiper, W. Wilson, and R. J. Cashman.
No. 140. "Infrared Spectra of Planets," by Gerard P. Kuiper.
No. 141. "Eclipsing Binaries with *Ca* II Emission," by W. A. Hiltner.
No. 142. "The Balmer Discontinuity in the Spectrum of HD 190073," by Otto Struve.
No. 143. "*Fe* II Emission Lines in α Herculis and α Scorpii," by G. Herzberg.
No. 144. "Spectrographic Observations of the Eclipsing Binaries of the W Ursae Majoris Type AH Virginis and TZ Bootis," by Y. C. Chang.
No. 145. "Spectrophotometry of the F Stars and of τ Ursae Majoris. I," by Jesse L. Greenstein.
No. 146. "The Spectrum of γ Pegasi," by Anne B. Underhill.
No. 147. "J. S. Plaskett's Star of Large Mass, HD 47129," by Otto Struve.
No. 148. "The Intensities and Profiles of Lines in Some B-Type Stars," by Anne B. Underhill.
No. 149. "Star in Diffuse Nebulae," by Jesse L. Greenstein.
No. 150. "The Radial Velocity of RR Lyrae," by O. Struve and A. Blaauw.
No. 151. "Rapid Variations in the Spectrum of Rho Cassiopeiae," by Jesse L. Greenstein.
No. 152. "The Purity of Interstellar Hα Emission," by Thornton Page.
No. 153. "Spectroscopic and Photometric Observations of A Faint Wolf-Rayet Spectroscopic Binary," by W. A. Hiltner.
No. 154. "A Spectroscopic Study of Beta Aurigae," by Burke Smith.
No. 155. "Radial Velocities of Two Stars of the W Ursae Majoris Class," by Daniel M. Popper.
No. 157. "Spectrographic Observations of the Eclipsing Binaries RZ Comae, V 502 Ophiuchi, RV Corvi, and BF Virginis," by O. Struve and L. Gratton.
No. 158. "The Spectrum of Comet 1947 *n*," by P. Swings and Thornton Page.
No. 161. "Survey of Planetary Atmospheres," by Gerard P. Kuiper.

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